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# **The SusTEACH Methodology**

**Assessment of the environmental impacts of Higher Education  
Teaching Models and development of an Environmental  
Appraisal toolkit**

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**Faculty of Maths, Computing and Technology, The Open University.**

***SusTEACH -Sustainable Tools for the Environmental Appraisal of the  
Carbon Impacts of Higher Education (HE) Teaching Models***

**June 2012 (updated 2015)**

**DESIGN  
INNOVATION  
GROUP**



## Abstract

Sustainable, low carbon Higher Education (HE) teaching systems are part of the carbon reduction strategies needed to meet the targets set for HE institutions. Significant changes in the use of Information and Communication Technologies (ICTs) have led to new methods in teaching and learning, blending conventional and ICT-based teaching models. Little is known about their environmental impacts. Few studies have considered the whole system carbon-based environmental impacts of different systems of delivering Higher Education. One notable exception was the Factor 10 Visions study 'Towards Sustainable Higher Education', which offered an exemplar methodology for conducting an environmental impact audit/assessment of HE courses/modules. Building on this, the SusTEACH project examined the transformative effect of ICTs on HE teaching models, and developed a methodology to assess the main carbon-based environmental impacts of HE courses/modules, and to provide estimations of the energy and carbon impacts associated with different HE teaching models. This methodology as outlined here has supported the SusTEACH project research analysis of over thirty HE courses and modules, and the SusTEACH toolkit available from OpenLearn [The environmental impact of teaching and learning](#)

## Acknowledgements

We are grateful for the support of a large number of interested participants in the project from Cranfield University, Loughborough University, The Open University, and Oxford University.

The SusTEACH project has built on the environmental assessment methodology of the 'Factor 10 Visions Project' led by Roy, Potter *et al.* (2005) details of which are available at [http://www3.open.ac.uk/events/3/2005331\\_47403\\_o1.pdf](http://www3.open.ac.uk/events/3/2005331_47403_o1.pdf). The 'Factor 10 Visions Project' findings have been reanalysed to help with the development of the SusTEACH toolkit, see <http://www9.open.ac.uk/SusTeach/>

We would like to thank the Project Advisory Group: Professor Robin Roy, Professor Stephen Potter and Ms Carol Morris for their support and guidance.

We would also like to thank Dr Stephen Hallett, Cranfield University, for his considerable support with the web-tool development.

# The SusTEACH Methodology

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## Glossary

AL - Associate Lecturers

CATS credits – This refers to the standard UK Credit Accumulation and Transfer Scheme (CATS) system used in Higher Education. The CATS system identifies 1 CATS credit as equivalent to 10 hours total study and calculates that 360 CATS credits are required for an undergraduate degree and 180 credits for a Master's degree

FTE – Full time Equivalent

HE - Higher Education

HEI - Higher Education Institution

HEFCE - Higher Education Funding Council for England

ICT - Information and Communication Technologies

JISC - Joint Information Systems Committee

SusTEACH -Sustainable Tools for the Environmental Appraisal of the Carbon Impacts of Higher Education Teaching Models

OU - The Open University

VLE- Virtual Learning Environment

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*Report cover, shows the SusTEACH graphic designed to represent the development of tools to support the Environmental Appraisal of the Carbon Impacts of Higher Education (HE) Teaching Models tools using Information and Communication Technologies, (designed by S. Caird and S. Hallett).*

## Executive Summary

Sustainable, low carbon Higher Education (HE) teaching systems are part of the carbon reduction strategies needed to meet the targets set for HE institutions. The challenges of supporting the transition to a sustainable future have not been fully addressed by current systems and practices in Higher Education. Addressing these challenges needs to take account of the ongoing transformation of HE teaching systems in recent years as a result of widespread deployment of Virtual Learning Environments, Local Area Networks, wireless networks and cloud computing services in institutions. Significant changes in the use of Information and Communication Technologies (ICTs) have led to new methods in teaching, blending conventional and ICT-based educational models. There has been greater experimentation in the use of ICTs to support pedagogical innovation to enhance or replace traditional teaching methods, with most universities now having a Virtual Learning Environment to support qualification programmes.

Few studies have considered the whole system carbon-based environmental impacts of different systems of delivering Higher Education. One notable exception was the Factor 10 Visions study 'Towards Sustainable Higher Education', which assessed the environmental impacts of campus-based and distance teaching-based Higher Education systems (Roy *et al.*, 2005). The Factor 10 Visions project offered an exemplar environmental impact assessment methodology that the SusTEACH project builds on to examine the transformative impact of ICTs on HE Teaching Models and assess their environmental impacts.

The SusTEACH project aimed to assess the carbon-based environmental impacts associated with the planned teaching and learning delivery methods of different Teaching Models. This approach assumed that teaching delivery methods are an important direct influence on the environmental impacts of the course or module. The SusTEACH project developed a methodology to conceptualise and classify HE Teaching Models using ICTs that allows for an investigation of the main sources of environmental impacts associated with different teaching delivery methods, the supportive infrastructure and wider aspects of the Higher Education system.

The SusTEACH project gathered new data on thirteen courses or modules in four HE institutions, which were selected to represent diverse Teaching Models utilising ICTs for the teaching delivery. We also re-analysed the data gathered in the Factor 10 Visions project which conducted a large study of the environmental impacts of twenty courses or modules in fourteen HE institutions representing traditional face-to face and distance teaching models in UK institutions in England, Scotland and Wales (Roy *et al.*, 2005). The findings from the data analysis are reported separately.

There were a number of steps involved in undertaking this environmental impact assessment which are discussed in detail in this report.

### «««Step 1: Classifying HE Teaching Models using ICTs

We developed a methodology that allowed for an investigation of the carbon-based environmental impacts associated with HE Teaching Models using ICTs. This methodology conceptualised and classified HE Teaching Models in terms of different methods of delivering teaching and learning provision, and identified the role of ICTs in enhancing or replacing traditional teaching practices. The HE course and module data gathered from both the SusTEACH and Factor 10 Visions projects were classified within the Teaching Models framework, for inclusion in the project analysis.



*«««Step 2: Gathering primary data and accessing databases to estimate and model the environmental impacts of HE courses and modules.*

We identified and gathered data on the main sources of carbon-based environmental impacts associated with Higher Education teaching. The methodology included an assessment of travel; the consumption of energy for computing, residential heating and for powering campus sites; and the use of paper and printed matter for the preparation, delivery and study of courses or modules.

The SusTEACH project gathered course and module-related activity data from students and staff via questionnaire surveys, and accessed existing databases to support the modelling and estimation of energy impacts. The data collection process was designed to represent different HE teaching systems, including specific characteristics of the distance teaching system, such as the module production and presentation process, and transportation of teaching materials, as this may have different environmental impacts.

*«««Step 3: Normalising the data collected for comparative analysis*

There needed to be a mechanism for normalising the data collected to enable the comparison of the courses and modules under investigation and their differential environmental impacts. We adopted the standard UK Credit Accumulation and Transfer Scheme (CATS) as a time-based measure for comparing the environmental impacts of courses or modules. The CATS system identifies 1 CATS credit as equivalent to 10 hours total study including writing assignments, field work, etc. and calculates that 360 CATS credits are required for an UK undergraduate degree and 180 credits for a Master's degree. Normalising the data in this way allowed for inter-institutional and intra-institutional comparisons, as well as comparisons of both part-time and full-time delivery methods and impacts.

*«««Step 4: Establishing measures of energy consumption and carbon conversions for assessing environmental impacts.*

The source of environmental impacts was estimated from the data gathered on course or module activities. Fossil fuel energy consumption and CO<sub>2</sub> emissions were utilised as measures of environmental impacts as these are widely accepted indicators of environmental impact (Chambers et. al., 2000). The activity data gathered provided information on sources of Scope 1, 2 and some sources of Scope 3 CO<sub>2</sub> emissions. The course or module activity data was converted into energy consumption, and associated CO<sub>2</sub> data using the latest carbon conversion factors (AEA, 2011). The data obtained from the Factor 10 Visions project were also recalculated to determine their energy consumption and CO<sub>2</sub> emissions using up-dated conversion factors, for inclusion in the SusTEACH project analysis.

*«««Step 5: Compiling data into consistent forms for calculating course/module environmental and lifetime impacts*

Data for each environmental impact was organised into consistent forms and normalised using CATS credits (or hours of study) to provide the average energy consumption, and CO<sub>2</sub> emissions of a course or module per student per 10 CATS credits (which is equivalent to 100 hours of study). This allowed the energy impacts of different courses or modules to be directly compared and classified within the Teaching Models' framework. The analysis of impacts was widened to estimate the lifetime impacts of specific HE Teaching Models.

«««Step 6: *Developing an environmental appraisal toolkit to model HE teaching impacts.*

The SusTEACH project aimed to develop Sustainable Tools for the Environmental Appraisal of the Carbon Impacts of Higher Education (HE) Teaching Models using ICTs. The Toolkit includes tools designed to support: the modelling of HE teaching carbon impacts; the planning of more sustainable courses, modules and programmes; the collection of data on the teaching, learning and assessment activities in HE; and support carbon-based assessments and carbon reduction policies and contribute towards achieving more sustainable teaching practices in HE. These interactive tools and resources are available online at <http://www.open.ac.uk/blogs/susteach/>

# **The SusTEACH Methodology: Assessment of the environmental impacts of Higher Education Teaching Models and Development of an Environmental Appraisal toolkit**

## **Introduction**

Sustainable, low carbon Higher Education (HE) teaching systems are part of the carbon reduction strategies needed to meet the targets set for Higher Education Funding Council for England (HEFCE) funded institutions, which refer to reductions of 43 per cent by 2020 and 83 per cent by 2050 compared with 1990 baseline levels (see HEFCE, 2010). The challenges of supporting the transition to a sustainable future have not been fully addressed by current paradigms, structures and practices in Higher Education, according to a United Nations report which calls for systemic transformation towards a sustainable future (Tilbury, 2011).

Based on well-known definitions of sustainability (See <http://en.wikipedia.org/wiki/Sustainability>), it could be argued that sustainable education needs to meet the triple bottom line of: maintaining pedagogic effectiveness, achieving economic success outcomes, as well as the reduction of environmental impacts, including greenhouse gas emissions, consumption of natural resources, waste generation and the protection of biodiversity. Within this wider context, the present focus in HE has been mainly on the following:

Greening campus buildings;<sup>1</sup>

Sustainable procurement of products and services;<sup>2</sup>

Teaching *about* sustainability in the curriculum<sup>3</sup>;

Minimising the waste, energy and paper consumption of staff and students;

Supporting sustainability action community projects.

Addressing the challenges of sustainability needs to take account of the ongoing transformation of HE teaching systems in recent years as a result of widespread deployment of Virtual Learning Environments (VLE), Local Area Networks (LAN), wireless networks and cloud computing services in institutions. There has been greater experimentation in the use of Information and Communication Technologies<sup>4</sup> to support pedagogical innovation to enhance or replace traditional teaching methods. There are an increasing number of diverse teaching models using ICTs with most universities having a VLE to support qualification programmes. The concept of blended learning provision (see Collis and Moonen, 2001) is expected to become a dominant scenario in HE (Bates, 2001).

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<sup>1</sup> See the Carbon Trust, Higher Education case studies <http://www.carbontrust.co.uk/about-carbon-trust/case-studies/public-sector/higher-education/pages/default.aspx>

<sup>2</sup> This has led for example, to the Proco2 project on reducing CO<sub>2</sub> emissions (Scope 3) associated with HE procurement <http://www.jisc.ac.uk/whatwedo/programmes/greeningict/organisational/proco2.aspx>

<sup>3</sup> Also known as Education for Sustainable Development  
<http://educationforsustainabledevelopment.com/blog/>

<sup>4</sup> Information and Communication Technologies (ICTs) refer to digital resources and teaching and learning technologies utilised for preparation, administration, teaching and learning on courses and modules which are supported by ICT devices, including personal computers, laptops, Tablet devices, smart phones and software etc.

Few studies have considered the whole system carbon-based environmental impacts of different systems of delivering HE. One notable exception was the Factor 10 Visions study 'Towards Sustainable Higher Education', which assessed the environmental impacts of campus-based and distance teaching-based Higher Education systems (Roy *et al.*, 2005). The Factor 10 Visions study found that on average the production and delivery of distance teaching consumed nearly 90% less energy and produced 85% fewer CO<sub>2</sub> emissions than campus-based HE courses and modules (Roy *et al.*, 2005).

The Factor 10 Visions study took place at a time when there was limited ICT-based pedagogical innovation in UK HE, and therefore the study needed to be updated and extended. Not only have more campus-based institutions moved towards using more technology-enhanced teaching and learning support, providing a greater range of digital educational resources, but advances in ICT has enabled distance teaching institutions to integrate more technologies, to offer, or replace learning experiences which had been only previously available in the classroom or at residential schools. This suggests some blurring of boundaries between distance-based and campus-based HE systems in the UK.

The SusTEACH project aimed to examine the transformative impact of ICTs on HE Teaching Models and to assess their carbon-based environmental impacts. This study builds on the Factor 10 Visions project which offered an exemplar environmental impact assessment methodology as the basis for the SusTEACH project (Roy *et al.*, 2005). The methodology included an assessment of travel; the consumption of energy for computing, residential heating and for powering campus sites; and the use of paper and printed matter for the preparation, delivery and study of courses or modules<sup>5</sup>.

The SusTEACH project aimed to assess the environmental impacts associated with the planned teaching and learning methods of different Teaching Models. This approach assumes that teaching delivery methods are an important direct influence on the environmental impacts of the course or module. The SusTEACH project developed a methodology to conceptualise and classify HE Teaching Models using ICTs that allows for an investigation of the main sources of environmental impacts associated with different teaching delivery methods, the supportive infrastructure and wider aspects of the Higher Education system.

The SusTEACH project re-analysed the data gathered in the Factor 10 Visions project which conducted a large study of the environmental impacts of twenty courses or modules in fourteen HE institutions representing traditional face-to face and distance teaching models in UK institutions in England, Scotland and Wales (Roy *et al.*, 2005). In addition, the SusTEACH project gathered new data on thirteen courses or modules in four HE institutions, which were selected to represent diverse Teaching Models utilising ICTs for the teaching delivery. Both datasets are combined for analysis within a Teaching Models' framework.

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<sup>5</sup> The SusTEACH project focuses on the course/module level in the context of undergraduate or post-graduate educational qualification programmes. The terms course and module are both used within and across HEIs, to refer to a set of modular, standardised, independent, or interrelated teaching units that when appropriately combined, construct a degree qualification. The term course may have a second meaning when used to refer to a course of study on a qualification programme which may consist of several modules or courses. To avoid confusion the term course is used in the first sense, and we refer throughout to course/module.

There were a number of steps involved in undertaking this environmental impact assessment which are discussed in detail below.

#### *Step 1: Classifying HE Teaching Models using ICTs*

We developed a methodology that allowed for an investigation of the carbon-based environmental impacts associated with HE Teaching Models using ICTs. This methodology conceptualised and classified HE Teaching Models in terms of different methods of delivering teaching and learning provision, and identified the role of ICTs in enhancing or replacing traditional teaching practices. The HE course and module data from both the SusTEACH and Factor 10 Visions projects were classified within the Teaching Models framework, for inclusion in the project analysis.

#### *Step 2: Gathering primary data and accessing databases to estimate and model the environmental impacts of HE courses and modules.*

We identified and gathered data on the main sources of carbon-based environmental impacts associated with Higher Education teaching, building on the approach of the Factor 10 Visions study (Roy *et al.*, 2005). The SusTEACH project gathered course and module-related activity data from students and staff via questionnaire surveys, and accessed existing databases to support the modelling and estimation of energy impacts. This provided most of the data required to calculate course or module-related impacts associated with: the use of transport, ICTs, materials and residential energy consumption. We estimated residential accommodation and campus energy consumption impacts by combining data obtained from questionnaires with existing databases. In addition, the data collection process needed to represent different HE teaching systems, including specific characteristics of the distance teaching system, such as the module production and presentation process, and transportation of teaching materials, as this is expected to have different environmental impacts (Roy *et al.*, 2005).

#### *Step 3: Normalising the data collected for comparative analysis*

There needed to be a mechanism for normalising the data collected to enable the comparison of the courses and modules under investigation and their differential environmental impacts. We adopted the standard UK Credit Accumulation and Transfer Scheme (CATS) system as a time-based measure for comparing the environmental impacts of courses or modules. The CATS system identifies 1 CATS credit as equivalent to 10 hours total study including writing assignments, field work, etc. and calculates that 360 CATS credits are required for an UK undergraduate degree and 180 credits for a Master's degree<sup>6</sup>. Normalising the data in this way allowed for inter-institutional and intra-institutional comparisons, as well as comparisons of both part-time and full-time delivery methods and impacts.

#### *Step 4: Establishing measures of energy consumption and carbon conversions for assessing environmental impacts.*

The source of environmental impacts was estimated from the data gathered on course or module activities. Fossil fuel energy consumption and CO<sub>2</sub> emissions were utilised as measures of

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<sup>6</sup> The standard UK Credit Accumulation and Transfer Scheme (CATS) system partly matches the European credit transfer scheme ECTS which runs as part of the Bologna process within the European higher education area. See [http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide\\_en.pdf](http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide_en.pdf).

environmental impacts as these are widely accepted indicators of environmental impact (Chambers et. al., 2000). The activity data gathered provided information on sources of Scope 1, 2 and some sources of Scope 3 CO<sub>2</sub> emissions (see [http://www.hefce.ac.uk/pubs/hefce/2010/10\\_01/](http://www.hefce.ac.uk/pubs/hefce/2010/10_01/)). The course or module activity data was converted into energy consumption, and associated CO<sub>2</sub> data using the latest carbon conversion factors issued by the UK Departments for Environment, Food and Rural Affairs and Energy and Climate (the Defra/DECC Conversion Factors for Company Reporting) (AEA, 2011). The data on the course and module-related activities obtained from the Factor 10 Visions project were also recalculated to determine their energy consumption and CO<sub>2</sub> emissions using up-dated conversion factors, for inclusion in the SusTEACH project analysis.

*«««Step 5: Compiling data into consistent forms for calculating course/module environmental and lifetime impacts*

Data for each environmental impact was organised into consistent forms and normalised using CATS credits (or hours of study) to provide the average energy consumption, and CO<sub>2</sub> emissions of a course or module per student per 10 CATS credits (which is equivalent to 100 hours of study). This allowed the energy impacts of different courses or modules to be directly compared and classified within the Teaching Models' framework.

The analysis of impacts was widened to estimate the lifetime impacts of specific HE Teaching Models. The concept of the standard lifetime of a course/module varies to some extent between institutions. It is of particular interest to distance education providers, such as The Open University (OU) where there is a significant investment in the module production process. This is important to consider because savings on CO<sub>2</sub> emissions and economic payback is partially determined by the expected number of students participating over the module lifetime, the ratio of staff to students, as well as other characteristics of the teaching system and campus site facilities.

*«««Step 6: Developing an environmental appraisal toolkit to model HE teaching impacts.*

The SusTEACH project aimed to develop Sustainable Tools for the Environmental Appraisal of the Carbon Impacts of Higher Education (HE) Teaching Models using ICTs. The Toolkit includes tools designed to support: the modelling of HE teaching carbon impacts; the planning of more sustainable courses, modules and programmes; the collection of data on the teaching, learning and assessment activities in HE; and support carbon-based assessments and carbon reduction policies and contribute towards achieving more sustainable teaching practices in HE. These interactive tools and resources are available online at <http://www9.open.ac.uk/SusTeach/>

To explain the methodology further, this paper sets out the issues associated with:

Classifying HE Teaching Models using ICTs;

Gathering primary data to estimate the environmental impacts of HE courses and modules;

Normalising the data collected for comparative analysis;

Establishing measures of energy consumption and carbon conversions for assessing the impacts of HE courses and modules;

Gathering data and accessing databases to model and estimate the residential energy and site energy impacts of HE courses and modules;

Compiling data into consistent forms for calculating course/module environmental and lifetime

impacts;

Developing the SusTEACH Environmental Appraisal Toolkit to support the modelling of HE teaching impacts.

### Classifying HE Teaching Models using ICTs

The utilization of ICTs in HE teaching and learning provision potentially creates many diverse, blended Teaching Models. We aimed to conceptualise and classify HE Teaching Models in terms of the different methods of delivering the teaching and learning provision, and the role of ICTs in enhancing or replacing traditional teaching practices. A methodology for classifying HE Teaching Models was needed to provide the basis for conducting a carbon assessment of courses or modules and comparing their environmental impacts.

A key contribution to conceptualising different HE Teaching Models using ICTs comes from research on learning design and some e-learning models which developed technical standards for describing the way a 'unit of learning' and its component parts is designed. Building on this body of work, ideas on learning design were integrated with learning theories, activities and outcomes (Conole and Fill, 2005, p8) and this identified Teaching Models as having the following characteristics:

- Learning and teaching theories and models (e.g. constructivism, cognitivism, behaviourism) that underlie and inform the planned learning outcomes, and the development of educational resources and curricula.
- Learning activities that are undertaken as part of the teaching, learning and assessment provision. The learning design specifies the types of tasks, techniques, tools, human and technical resources, the learning sequences, communication and interactions, and roles to support learning provision. It also specifies the outcomes to be assessed.
- The pedagogic context, which includes the subject, the level of difficulty, the intended learning outcomes at the module/course level within the qualification programme.
- The wider environment context, including the HE infrastructure supporting the learning provision (e.g. the VLE infrastructure, ICTs and equipment, printed paper and resources, and the use of power and heat for facilities). It also includes transport infrastructure to and from places where the teaching or learning takes place, and student accommodation. For distance education models, this also includes the infrastructure for printing, storing and transporting materials between warehouses, student and tutors' homes, and campus and study sites.

The SusTEACH project builds on key educational initiatives at The Open University (OU), such as the Curriculum Business Models initiative which aims to provide a framework for fostering efficient and innovative module planning and design, and the Learning Design Initiative which aims to develop and implement a learning design methodology and suite of practical tools, resources, and innovation in HE to combine good pedagogic practice and the effective use of new technologies (see [www.open.ac.uk/blogs/OULDI/](http://www.open.ac.uk/blogs/OULDI/)). The teaching, learning and assessment provision is understood to have the following main characteristics (The OU, 2010, p17):

- Teacher-directed provision: This includes: the teaching guidance, educational content and library resources;
- Student-directed provision: This refers to the support for student: activities and thinking, reflection and work on assignments;
- Provision for communication and collaboration between staff and students, and between students;

- Assessment provision: This includes formative and summative assessment.

The SusTEACH project also considered various approaches to assessing ICT-intensiveness, including developing qualitative measures of the amount and type of ICTs adopted to enrich the teaching, learning, and assessment provision. This needed to take account of the following:

- The integration of ICTs in online and/or offline teaching and learning provision;
- The use of ICTs to replace and/or enhance teaching;
- The richness of the media used for the provision, where rich media support more comprehensive interactive, integrated, and specially designed online teaching, that permits greater synchronicity in online teaching, learning, communication and collaboration.

There has been interest in evaluating the online intensity of modules as the OU moves towards a greater online teaching, learning and assessment provision (The OU, 2010). Building on this approach, we developed qualitative measures to assess the ICT intensiveness of teaching delivery methods. To ensure applicability to different Teaching Models in Higher Education, we considered the methods that could be utilised to deliver the teaching, learning and assessment provision and developed qualitative measures of the main teaching delivery methods, including:

- Face-to-face teaching, which depends heavily on campus facilities, laboratories, computing devices, and equipment;
- Distance-teaching, using bespoke specially developed print-based teaching materials;
- ICT-enhanced teaching, using ICTs to add to the teaching and learning provision, such as providing online links to educational resources or with offline audio-visual digital resources and ICTs, e.g. CD's and DVD's;
- Online teaching, using ICTs to replace other teaching and learning delivery methods and that may include rich media.

This approach allowed the investigation of HE teaching delivery methods to include face-to-face teaching, the use of printed teaching materials, and the use of ICTs to enhance or replace teaching methods, as well as blended methods. We considered that by identifying the main teaching delivery methods, we could proceed to classify the various traditional and blended delivery methods used in HE. This led to the classification of courses or modules within a Teaching Models framework using lecturers' assessments, as follows:

1. **The Face-to-Face Teaching Model:** Teaching, learning and assessment is mainly provided using face-to-face teaching methods. This model is defined by a high face-to-face teaching delivery and no ICT-enhancement. The use of teaching materials is usually not high. Face-to-face teaching is associated with a higher use of student residential accommodation and campus site energy impacts.
2. **The ICT-Enhanced Face-to-Face Teaching Model:** Teaching, learning and assessment is provided using face-to-face teaching with some minimum enhancement by ICTs via online links to downloadable resources or with specially produced audio-visual digital resources and ICTs. The use of teaching materials is usually not high. Face-to-face teaching is associated with a higher use of student residential accommodation and campus site energy impacts.
3. **The Distance Teaching Model:** Teaching, learning and assessment is mainly provided using specially developed print-based distance teaching materials. This model is defined by a high use of printed teaching materials and may have low or no ICT-enhancement of the teaching



delivery. Face-to-face teaching is usually low. Campus site energy impacts are relatively low and there is no residential student accommodation.

4. **The ICT-Enhanced Distance Teaching Model:** Teaching, learning and assessment is provided using printed teaching materials but is strongly enhanced by ICTs via online links to downloadable resources or with specially produced audio-visual digital resources. Face-to-face teaching is usually low. As students make little use of campus facilities, the site energy use is relatively low and there is no residential student accommodation.
5. **The Online Teaching Model:** Teaching, learning and assessment is mainly provided online using ICTs and digital resources available on the university websites and Virtual Learning Environment. This model is defined by a strong online teaching delivery. Face-to-face teaching is usually low. The use of printed teaching materials is usually not high. As students make little use of campus facilities, the site energy use is relatively low and there is no residential student accommodation.

The Face-to-Face and ICT-enhanced Face-to-Face Teaching Models are both campus-based systems whereas the Distance, ICT-enhanced Distance and Online Teaching models are all usually offered within distance teaching systems. Following the Factor 10 Visions study we expected to find significant differences between the environmental impacts of campus-based and distance teaching systems. The lower impacts of distance-teaching compared with campus-based teaching were mainly due to: a reduction in the amount of student travel; economies of scale in the utilization of campus site facilities; and the elimination of almost all of the student residential energy (Roy *et al.*, 2005). This finding is consistent with evidence that campus site and residential energy consumption is a key source of HE carbon impacts (HESA, 2011).

We hypothesised that specific teaching delivery methods would have different environmental impacts, associated with: staff and student travel; the purchase and use of ICTs; the use of paper and printed material; residential accommodation and energy use; and campus site energy consumption. Specifically we expected that:

- Face-to-face teaching methods used for the teaching and learning provision would influence student travel, the requirement for residential accommodation and the use of campus accommodation and facilities.
- Printed teaching materials (e.g. distance methods) used for the teaching and learning provision would influence print purchases and paper consumption.
- ICTs used to enhance or replace other teaching methods would influence ICT purchases, and the time spent computing and online.

The SusTEACH research methods were designed to identify the environmental impacts of HE courses or modules and the data was analysed using the Teaching Models framework. As SusTEACH aimed to develop an Environmental Appraisal Toolkit, this analytical approach was useful for the design and development of the SusTEACH Planning and Modelling Tools. These tools were developed as a result of modelling the energy impacts associated with specific teaching delivery methods and Teaching Models.

#### **Gathering data to estimate and model the environmental impacts of HE courses and modules**

Building on the approach taken in the Factor 10 Visions study (Roy *et al.*, 2005), the SusTEACH project identified the main sources of carbon-based environmental impacts associated with Higher Education teaching, as follows:

- Travel to and from places where the teaching or learning takes place;
- ICT device purchase, and use for connecting to university websites and the VLE and for offline study;
- Paper, print and other educational resources;
- Student residential accommodation;
- Additional study-related home energy consumption (for heating, printing and lighting);
- Campus site energy consumption providing power and heat.

In addition, the data collection process needed to represent different HE teaching systems, including specific characteristics of the distance teaching system, such as the module production and presentation process, and transportation of teaching materials, as this is expected to have different environmental impacts (Roy *et al.*, 2005).

**Box 1: Main characteristics of two broad HE teaching and learning delivery systems: campus-based or distance HE teaching systems.** (updated from Roy *et al.*, 2005, p.12).

**Campus-based HE teaching systems** are characterised by a single or multi-site campus sites offering face-to-face teaching to students living either in temporary accommodation or at home, from where students commute to and from the campus to attend lectures, use libraries, laboratories, etc. For many students in temporary accommodation there is also travel between their main or usual 'home' and term-time/semester residences. In the campus-based system, teaching staff plan the course/module and present lectures and tutorials to relatively small numbers of students (usually <100), with some degree of face-to-face teaching, and travelling from home to the campus and to other sites as required (for example to off-campus field trips).

**Distance teaching systems** are designed to offer greater flexibility in education and reach significantly larger numbers of students. Specially developed educational material is prepared by an academic production team and delivered online or by mail to students for part-time study at home. Some distance teaching systems, such as The Open University, offer tutorials or day schools supported by tutors called Associate Lecturers which may be held online, using software such as Elluminate, or face-to-face in regional study centres. Further support is offered via email, computer conferencing, mail and telephone. Modules are also supported by academic presentation teams who work on minor revisions to teaching materials, planning tutorials or day schools and student assessment. Some modules offer residential elements that may be up to a week-long.

Specific characteristics of the distance teaching system include the infrastructure for printing, storing and transporting materials between warehouses, student and tutors' homes, and campus and study sites. The distance system also includes a Virtual Learning Environment (VLE) infrastructure although most UK HE systems now have a VLE to support their qualification programmes. A typical VLE provides students with online access to materials in electronic format, such as lecture or tutorial documents, assignments, timetables, and discussions forums. VLEs have specific server architectures although there may be different physical and virtual server technologies in different HE institutions.

We gathered primary data on course or module-related activities that are associated with environmental impacts from students and staff via questionnaire surveys. Questionnaires provided most of the data required to calculate course or module-related impacts associated with travel; the purchase and use ICT devices; the consumption of paper and printed material; and residential energy consumption. We combined data obtained from questionnaires with existing databases to estimate campus energy consumption impacts, and model data to estimate residential accommodation impacts.

A methodological limitation of this study is the reliance on the respondents' memory in estimating the time spent using energy for course or module-related activities. It may have been more accurate to have tracked student and lecturers' impacts through the phases of the development and delivery of teaching and learning, but due to the short project time-scales, the data was collected retrospectively.

We used specially-designed questionnaires to gather primary data on staff and student course or module-related travel, and ICT and print usage (see Appendix 1 for a sample student questionnaire). The questionnaires were emailed via a survey link with data managed and collected by The OU Institute of Educational Technology (IET) survey services. Questionnaires were either directly emailed to staff or students in the OU or emailed via one of the lecturers at the other Universities who had agreed to participate in the SusTEACH project.

The questionnaires gathered environmental impact data based on time periods, such as 'the typical week' and calculated total impacts by multiplying environmental impacts for the typical week by the number of course/module weeks. The questionnaires also gathered information on time periods such as 'during the whole module/course', and 'a previous academic year' and the data gathered were apportioned to the course/module. We asked lecturers about the total number of days spent working on the module to calculate lecturers' overall module impacts to take account of teaching spread over the term(s) or semester(s) compared with shorter, more intensive courses/modules. Response categories were offered and we used the mid-points of numerical categories to support analysis.

Questionnaires were designed to gather data on a consistent basis. There were some variations in the questionnaire forms to avoid asking for information already available from existing databases. For example, it was possible to obtain independent information on the travel of Associate Lecturers associated with The Open University modules from existing claims' databases.

Questionnaires were also designed to represent key differences between the HE Teaching Models such as:

1. **Distance-teaching** models require different student travel patterns to campus-based models.
2. Specific characteristics of the distance teaching system needed to be represented such as the module production and presentation process, as well as transportation of teaching materials.
3. Different uses of terminology between HE institutions needed to be represented, for example the concepts of course or module were both used.

4. Differences in the structure of qualification programmes may present courses/modules in parallel or in intensive time blocks during terms or semesters.

It was not always possible to design questionnaires to represent all HE Teaching Models. This was particularly the case when courses/modules did not have clear boundaries within their qualification programme. The data gathered, consequently could not be normalised using the CATS credit system (see footnote 5), and the student and staff activities and impacts could not be assessed.

We found that with some courses/modules there was no 'typical week' as they were structured differently during the teaching programme. This applied particularly to post-graduate courses/modules where student learning could take place during various periods of intense face-to-face teaching, followed by remote study or work on assignments/projects off-campus. Variation in the structure of modules or courses could be associated with different travel pattern, and students using several residences. We worked on tailoring the questions and data analysis to address these variations and their implications for calculating course/module impacts.

#### **Normalising the data collected for comparative analysis**

There needed to be a mechanism for normalising the data collected to enable the comparison of the courses and modules under investigation and their differential environmental impacts. We adopted the standard UK Credit Accumulation and Transfer Scheme (CATS) system as a time-based measure for comparing the environmental impacts of courses or modules. The CATS system identifies 1 CATS credit as equivalent to 10 hours total study including writing assignments, field work, etc. and calculates that 360 CATS credits are required for an UK Undergraduate degree and 180 credits for a Master's degree. Normalising the data in this way allows for inter-institutional and intra-institutional comparisons, as well as comparisons of both part-time and full-time delivery methods and impacts. The standard UK CATS system partly matches the European Credit Transfer Scheme (ECTS) which runs as part of the Bologna process within the European higher education area, (see [http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide\\_en.pdf](http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide_en.pdf)).

Teaching plans do not always turn out as expected and students may spend more or less time learning than planned by lecturers and academic designers. As there may be discrepancies between planned and actual learning time, this may lead to an overestimation or underestimation of the environmental impacts of teaching. In particular, time spent learning using ICTs, depends on a number of intrinsic and extrinsic factors (e.g. digital literacy skills and familiarity with new software tools, and disability, other personal matters) (Mayes, 2004). We aimed to examine the relationship between planned study hours (as indicated by CATS credits) and actual study hours in the data collected from students and VLE activity data.

#### **Establishing measures of energy consumption and carbon conversions for assessing impacts**

The environmental impacts of HE teaching were measured utilising two widely accepted measures, to convert course or module activity data to fossil fuel energy consumption and CO<sub>2</sub> emissions (Chambers et. al. 2000). Carbon conversion factors associated with energy consumption are regularly updated, and consequently we needed to gather the most up-to-date data available to assess the course/module activity data gathered for the SusTEACH project. The primary source for converting activity data to energy use and CO<sub>2</sub> emissions were the widely used Defra/DECC Conversion Factors for Company Reporting which provides conversion factors for all fuel sources based on units of consumption and for transport modes (AEA, 2011).

The Defra/DECC conversion factors are used in HE to support carbon management plans to achieve carbon reduction targets against a 2005 carbon emissions baseline, (see [http://www.hefce.ac.uk/pubs/hefce/2010/10\\_01/](http://www.hefce.ac.uk/pubs/hefce/2010/10_01/)). The HEFCE Carbon Reduction Target and Strategy for Higher Education in England specifies that Scope 1 and 2 emissions data should be collected and compared against the carbon baseline. Scope 1 emissions arise from sources that are owned or controlled by the HE institution, such as for example, emissions from on-site combustion of fossil fuels or transport fuel used by vehicle fleets. Scope 2 refers to emissions from the generation of electricity consumed by the institution. Scope 3 emissions are difficult to monitor and report and refer to all emissions that are a consequence of HE activities, but arise from sources not owned or controlled by the institution. This includes for example, emissions from travel for teaching, learning, research, administration and general work; the procurement of goods and services; and waste, water and land use.

The data gathered for the SusTEACH project provided information on sources of emissions associated with course or module-related activities. The AEA report (2011) calculates the emission factors differently for direct and indirect greenhouse gas (GHG) emissions based on the following: *Direct GHG emissions* are emitted at the point of use of a fuel/energy carrier or fuel combustion (or in the case of electricity, at the point of generation); *Indirect emissions* are emitted prior to the use of a fuel/energy carrier or in the case of electricity, prior to the point of generation.

For the SusTEACH assessment of the main sources of carbon-based environmental impacts associated with Higher Education teaching, we focused mainly on measures of delivered energy and direct emissions of fossil fuels at the point of use, as this was a consistent measure provided by most data sources on CO<sub>2</sub> emissions. Delivered energy refers to the amount of energy delivered with no adjustment made for the fuels consumed and their indirect emissions during the production prior to the point of use or fuel combustion. By contrast, embodied energy refers to primary energy consumed over the life-cycle of a product or system associated with extraction, production, distribution, use and eventual disposal giving rise to indirect emissions which need to be established with reference to life-cycle environmental impact assessments.

The delivered electricity emission factors are based on the UK national grid per kWh of electricity used and include transmission and distribution losses. The Defra/DECC guidelines suggested that a 5 year 'grid rolling average' of direct emissions was acceptable for calculating electricity emissions (Scope 2), however we used the more precise actual in-year non-rolling average instead. Delivered transport energy was measured using emissions factors including: Scope 1 emissions associated for example, with car and motorbike transport modes; and some sources of Scope 3 emissions, such as using bus, rail and air transport modes. The SusTEACH project calculated CO<sub>2</sub> emissions for delivered energy using the following conversion factors as appropriate:

Electricity based on 0.482Kg of CO<sub>2</sub> per kWh

Gas based on 0.204Kg of CO<sub>2</sub> per kWh

Oil based on 0.279Kg of CO<sub>2</sub> per kWh

Diesel based on 0.257Kg of CO<sub>2</sub> per kWh

LPG based on 0.229Kg of CO<sub>2</sub> per kWh

Hybrid petrol based on 0.248Kg of CO<sub>2</sub> per kWh

Aviation spirit based on 0.25985Kg of CO<sub>2</sub> per kWh (AEA, 2011)

The embodied energy consumed during the manufacture of transport vehicles, heating systems, printers, or lighting used for study were not included in the environmental impact assessment because it would have added unmanageable complexity to the calculation of the proportional impact that should be attributed to courses/modules. It was appropriate, however, to refer to embodied energy figures for paper, printed materials, and ICT equipment, identified by life-cycle environmental assessment studies. This was not a straightforward process, as at times we found that there were several conversion factors available for sources of environmental impacts which could be used and therefore choices needed to be made. We decided to use the most reputable, well-researched and most up-to-date carbon conversions factors, discussed in detail later in this report.

### **Transport data collection and assessment**

Following the Factor 10 visions project, the travel data gathered included information on student and staff course/module-related travel which was categorised into types of trip, number of trips, round trip distance and mode of travel, as well as regular and occasional term-time /semester travel. Staff and students at campus universities were also questioned about regular commuting during 'the typical week' as well as travel between their term-time address and main home residence.

The formula for calculating regular and occasional term-time/semester transport impacts follows:

$$(\text{Total distance per week travelled/No. of students}) \times (\text{Length of course or module in weeks}) \times (10 \text{ CATS credits/CATS credits per course or module}).$$

A difficult methodological issue was how to apportion trips with several purposes, such as study plus work or shopping, and attribute the appropriate travel impact to the course or module being investigated. Questions were worded carefully to gather travel information, making it possible to apportion the transport impacts specifically to the course or module.

For campus-based students, we calculated the impacts of their journeys to and from their main home at the beginning and end of term/semester. As this travel is associated with all their studies during the term/semester, this needed to be apportioned to the course/module under investigation. The formula for calculating travel at the beginning and end of the term/semester follows:

$$(\text{Total distance/No. of students}) \times (\text{CATS credits per course or module/CATS credits per term or semester}) \times (10 \text{ CATS Credits/CATS credits per course or module}).$$

Travel data was converted into average energy consumption and CO<sub>2</sub> per student, using carbon conversion data associated with using the different travel modes and fuels and expressed per 10 CATS credits.

### **Transport energy use and CO<sub>2</sub> emissions**

Travel impacts were measured from the distance travelled during the course or module. The 2011 Defra/DECC Conversion Factors provided data for all modes of passenger transport using fossil fuels and was used to convert the distance travelled by each respondent to energy use and CO<sub>2</sub> emissions.

We followed the approach of the Factor 10 Visions study, where car fuel consumption was calculated for car drivers excluding passengers. Although this underestimates car fuel use, it would have been difficult to allocate fuel use per passenger, without making further estimations about car occupancy levels. The occupancy for a car and motorbike was therefore assumed to be 1 person. The assumed occupancy levels for all other modes of transport were determined by Defra/DECC and reflected in their conversion factors.

The Defra/DECC conversion factors showed considerable variation in the energy impacts associated with car engine size and the type of fuel used (Appendix 1, Table 1). Data for electric vehicles were not included in these conversion factors, and was taken from a study by Howey *et al.*, (2011) that compared the energy consumption of electric, hybrid and internal combustion engine vehicles. The energy impacts of electric vehicles are significantly lower than the average car impacts, although no respondents were using this mode of transport.

The SusTEACH project collected information on staff and student car engine size and the type of fuel used. It would have been impractical to calculate conversion factors for each individual's car based on this information, so we used the data to produce average figures, which were applied to calculate the energy impacts of all car user travel. The average car engine size from student respondents to the survey was 1.6 litres and the ratio of petrol to diesel cars was 2:1. Very similar figures were calculated from lecturers' data; therefore the aggregates for car transport impacts presented in Table 1 are based on this ratio.

**Table 1 Transport energy use and emissions**

Mode of transport	Energy consumption (MJ) per passenger mile	CO <sub>2</sub> emissions (Kg) per passenger mile
Electric Car	0.99	0.15
Motorbike	2.715	0.187
Local bus	3.334	0.238
Express Coach	0.658	0.047
Rail	0.83	0.085
Metro/Tube/Tram	0.853	0.114
Air (long haul)	2.79	0.110
Air (short haul)	2.45	0.096

Mode of transport <i>continued</i>	Energy consumption (MJ) per passenger mile	CO <sub>2</sub> emissions (Kg) per passenger mile
<b>Car<sup>7</sup></b>	<b>4.36</b>	<b>0.304</b>
Petrol (< 1.3 litre engine)	3.977	0.274
Petrol (1.3 - 1.6 litre engine)	4.500	0.31
Petrol (1.6 - 2 litre engine)	4.935	0.34
Petrol (> 2 litre engine)	6.968	0.48
Diesel (< 1.3 litre engine)	3.236	0.231
Diesel (1.6 - 2 litre engine)	4.034	0.288
Diesel (> 2 litre engine)	5.45	0.389
LPG Medium (< 1.6 engine)	4.81	0.306
LPG large (> 1.6 engine)	6.791	0.432
Hybrid petrol (< 1.6 engine)	2.745	0.189
Hybrid petrol (> 1.6 engine)	4.907	0.337

#### ICT data collection and assessment

The Factor 10 visions project gathered staff and student data on the time spent using off-campus computers for course or module related tasks per week, and the purchase of computer equipment and software mainly for the course/module. The use of ICTs on campus sites was excluded, as this energy data was included in the overall site energy consumption data.

The SusTEACH project followed this methodology but also asked students and staff about their *total* ICT use and specific use of ICT devices e.g. Desktop Personal Computer, Lap-top, Tablet device, or other portable technologies, such as personal media players, mobile phones. This is because we were interested in the use of ICT devices for teaching and learning, in addition to conducting an environmental impact assessment of course and module energy use.

We collected information which allowed us to apportion the time spent by student using ICTs: for offline and online study, including university websites; and in different locations, including university campus locations, home, term-time address, work, and in-transit.

The following formula was utilised for calculating ICT impacts per 10 CATS credits:

(Time (*using a median time of ICT usage*) x (frequency/No. of students) x (duration of course or module in weeks x (10 CATS credits/ course or module CATS credits)).

<sup>7</sup> Based on average car engine size 1.6 litres and petrol to diesel ratio of 2:1.



ICT data was converted into average energy consumption and CO<sub>2</sub> per student, using carbon conversion data associated with using different ICT devices both offline or connected to the Internet for study and expressed per 10 CATS credits.

#### Use of ICT devices and CO<sub>2</sub> emissions

The power consumption figures for the use of desktop PCs, laptop PCs, and monitors were obtained from the SusteIT Footprinting Tool (2009) which was designed to help Further and Higher Education institutions to estimate energy consumption and CO<sub>2</sub> emissions from non-residential ICT usage. This provides figures for the power consumption of active devices.

The SusTEACH questionnaires were designed to categorise desktop PCs according to their power consumption when active, with respondents able to select a low (30 watts per hour), medium (60 watts per hour), or high powered (100 watts per hour) PC. Respondents using a desktop PC were also asked to confirm the type of monitor used, which was important as the energy consumption of an older CRT monitor (70 watts per hour) is significantly different from an LCD/TFT monitor (35 watts per hour). For Laptop PCs the power consumption was estimated by SusteIT to be 35 watts per hour when active.

The energy and CO<sub>2</sub> emissions data for a Tablet device was difficult to estimate due to the wide range of Tablets available. We considered data for two different types of Tablet devices, the Apple iPad and Asus Eee PC. The iPad is typical of portable Tablet devices, whereas the Asus Eee PC is similar to a laptop PC, featuring a keyboard and a larger hard drive than the iPad. To determine the energy consumption, we divided the manufacturers' published data for the size of the battery by the expected hours of use that would be provided by a fully charged battery, with some variation found in the energy impacts of different tablet devices<sup>8</sup>. The questionnaires did not collect data on the particular Tablet model, however as the number of respondents using Tablet devices is still relatively low and the energy use for such devices is small relative to desktop or laptop PCs, this was not a significant issue for SusTEACH. A midpoint of the energy consumption for the two devices was therefore applied as a conversion factor, which produced a figure of 0.014MJ per hour.

A similar issue arose when trying to estimate the typical energy and CO<sub>2</sub> emissions for other portable devices, which include MP3 players, mobile phones, and e-readers. Energy consumption for portable devices was assessed using battery data for an Apple iPod and the Amazon Kindle<sup>9</sup>, which produced a figure of 0.0008MJ per hour. [The CO<sub>2</sub> emissions in Table 2 were calculated using the Defra/DECC conversion factor for electricity of 1kWh of electricity producing 0.482Kg CO<sub>2</sub>].

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<sup>8</sup> Apple iPad has a 25 watt hour battery and an estimated battery life of 10 hours, resulting in a power consumption of 2.5Wh = 0.0025kWh = 0.009MJ per hour. The Asus Eee PC has a 35 watt hour battery and an estimated battery life of 6.5 hours, resulting in a power consumption of 5.4Wh = 0.0054kWh = 0.019MJ per hour. Midpoint for the two devices is therefore 0.014MJ per hour

<sup>9</sup> iPod classic uses a 2 to 3 watt hour battery, depending on the model, and has a battery life of 30-40 hours for audio and 5-7 hours for video. Using a conservative real estimate of a 15 hour battery life and a 2.5 watt hour battery results in a power consumption of 0.17 Wh = 0.00017kWh = 0.0006MJ per hour. The Amazon Kindle uses a 6 watt battery, which Amazon suggests should last up to 30 hours. Using a conservative estimate of 20 hours produces a power consumption of 0.3Wh = 0.0003kWh = 0.001MJ. A midpoint for the two devices is therefore 0.0008MJ per hour

**Table 2 Use of ICT devices**

ICT device	Energy consumption (MJ) per hour	Kg CO <sub>2</sub> emissions per hour
Desktop PC (low powered)	0.108	0.014
Desktop PC (medium powered)	0.216	0.029
Desktop PC (High powered)	0.36	0.048
Laptop PC	0.108	0.014
CRT monitor	0.252	0.034
LCD/TFT monitor	0.126	0.017
Tablet device	0.014	0.002
Other portable technologies	0.0008	0.0001

### Internet activity and CO<sub>2</sub> emissions

The SusTEACH project showed that students spend a significant amount of their study time online. There is very little available research on the energy consumption and CO<sub>2</sub> emissions of the Internet. One notable exception is the recent report 'The Energy and Emergy of the Internet' which estimates the total power consumption for the Internet at between 170 and 307GW (Raghavan and Ma, 2011). This is the sum of the wall socket and embodied energy of devices and infrastructure that comprises the Internet.

As the SusTEACH methodology is focused on delivered energy, the embodied energy of the Internet infrastructure is not considered. The embodied energy of ICT devices has been examined separately, (discussed in Section on Use of ICT devices and CO<sub>2</sub> emissions) so this impact needed to be excluded to avoid double counting estimations of the Internet power consumption. Raghavan and Ma (2011) provide a lower and higher estimate of the wall socket power consumption of 44.6GW and 74.6GW respectively, which excludes the embodied energy of the Internet and of desktop and laptop PCs. Given such a wide range we took the mid-point of the two estimates of wall socket power consumption, namely 59.6GW.

The Raghavan and Ma report estimates that 144,000PB of data is transferred on the Internet each year, which would equate to 65MJ/GB if the upper estimate for total power consumption of 307GW is accepted. Using the figure for the power consumption of 59.6GW estimated above, the ratio of power consumption to data traffic is 12.62MJ/GB ( $65 \times (59.6/307)$ ). The estimate of 144,000PB of Internet data traffic is based on a year-end estimate for 2009 (Minnesota Internet Traffic Studies (MINTS), 2009). A more recent year-end estimate of 336,276PB of IP traffic for 2011 from Cisco (2011) suggested that Internet traffic has increased significantly since 2009. As MINTS report that their measurement of Internet traffic for 2009 was 'roughly consistent' with Cisco's for the same period, we therefore applied the current data from Cisco. The power/data ratio is therefore revised to 5.4MJ/GB ( $12.62 \times (144,000 / 336,276)$ ).

The SusTEACH questionnaires asked students how long they spent studying online, we consequently needed to convert the power consumption estimate per unit of Internet data traffic to the power consumption associated with time spent online. Ofcom (2011) reports, that the average residential customer uses 17GB of data per month when online. Assuming a household occupancy of 2.4, the average person is therefore using 7.08GB per person per month. The energy consumption of using 7.08GB of data is 38.23MJ ( $7.08 \times 5.4$ ) per person per month. The next step was to estimate the hourly impacts per person. An Ofcom communications market report (2011, p.256) states that the

average person spends 54.8 hours using an Internet-enabled computer per month, so the energy consumption of spending an hour connected to the Internet is 0.7MJ/per hour (38.23/54.8). This is higher than the estimate for Internet energy consumption in Factor 10 visions project of 0.45MJ/ per hour. Based on the Defra/DECC electricity carbon conversion factor of 0.482Kg CO<sub>2</sub> per kWh this produces emissions of 0.094Kg CO<sub>2</sub> per hour.

As students may be using computers to participate in online tutorials, the energy and emissions involved with this activity could be calculated by aggregating the energy and emissions figures for the use of a desktop or laptop PC with Internet activity. For example, a medium powered desktop PC with a TFT monitor consumes 0.342MJ and produces 0.0459Kg CO<sub>2</sub> per hour; this would increase to 1.042MJ and 0.1399Kg CO<sub>2</sub> per hour when connected to the Internet. Similarly, a laptop consumes 0.108MJ of energy, and produces 0.014Kg CO<sub>2</sub> per hour; this would increase to 0.808MJ and 0.108Kg CO<sub>2</sub> per hour when connected to the Internet. Based on accepting an equal weighting for desktop and laptop PC use, the mean energy consumption would be 0.93MJ with CO<sub>2</sub> emissions of 0.12Kg per hour.

### Virtual Learning Environments (VLE) and CO<sub>2</sub> emissions

The Virtual Learning Environment (VLE) is now an integral component of many HE courses and modules so it was important to consider the energy consumption of the equipment and infrastructure providing this service to students and staff. A typical VLE provides students with online access to materials in electronic format, such as lecture or tutorial documents, assignments, timetables, and discussions forums.

We attempted to collect data on different VLEs in the HE institutions participating in the SusTEACH project, but there were several difficulties. Outside The Open University, it was difficult to gain sufficient comparative data on the VLE energy consumption of other universities because the VLE architecture differs in each HE institution, and there are too many variables to make comparisons viable. This led us to conduct a detailed study of the OU's VLE which has been re-developed since 2005 and currently has approximately 150,000 unique visitors each month<sup>10</sup>, with a higher total user base.

The University's IT department provided information about the OU's VLE server architecture, storage requirements, and supporting computer room services and the energy consumption for each of these components. Even within the OU, apportioning energy consumption was complex due to the combination of physical and virtual server technology. The first step was to calculate the energy consumption of the additional supporting computer room services, such as the air conditioning and universal power supply attributable to the VLE IT equipment. The Power Utilisation Effectiveness (PUE) factor is measured by dividing the total computer room power consumption by the power consumption used to run the IT equipment. The PUE for the OU's two computer rooms averaged at 1.7 which was multiplied by the energy consumption calculated for the VLE's IT equipment to produce an estimate for the VLE energy consumption. The total energy consumption of the VLE was estimated as approximately 4000 watts or 14.4MJ per hour, producing CO<sub>2</sub> emissions of 1.92kg per hour.

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<sup>10</sup> The Open University Management Information Portal, (2012), *VLE Student Numbers*, Unpublished internal document, The Open University 17 January.

Based on an estimated 200,000 users supported by the VLE at the OU, this produces figures of 0.00007MJ consumed per student per hour. Using the Defra/DECC electricity conversion factor of 1kWh = 0.482Kg CO<sub>2</sub>, this results in relatively low emissions of 0.000001Kg CO<sub>2</sub> per student per hour. There is clearly a scale effect associated with a large user base. If the user base was only 10,000 users, which may be more typical of the number of students studying at a campus university, the energy consumption would be only 0.001MJ per student per hour.

VLE energy consumption may be calculated as KWH per minute per user multiplied by the duration of student VLE activity for a specific course/module and converted to energy and CO<sub>2</sub> impacts per 10 CATS credits. This impact would be useful when comparing the impacts of courses or modules that are online to a greater or lesser extent. This could also be applied to calculating the energy impacts of specific VLE tools, such as 'Elluminate' (see <http://www.illuminate.com>) and 'Forums' (<http://www.open.ac.uk/pc4study/communicating/why-the-ou-uses-online-forums.php>) in comparison with face-to-face teaching or materials-based alternatives.

The OU VLE data should however, not be treated as typical of VLE energy consumption, as they related to specific server architecture, and different blends of physical and virtual server technology may produce different results. Furthermore, we found that the VLE server architecture was changing at the OU with plans to transfer more operations to virtual servers. This should reduce energy consumption and CO<sub>2</sub> emissions, and implies that figures estimated for the SusTEACH project will change. However, the number of users is the key determinant of the VLE's energy consumption per student and the findings would not suggest that the VLE has a major carbon impact, even allowing for a different blend of physical/virtual servers and storage requirements.

#### **Purchases of ICT devices and CO<sub>2</sub> emissions**

The questionnaires were also designed to obtain information on purchases of new or upgraded computing equipment, mainly for study or teaching related to the course or module.

The literature showed that estimations of the embodied energy of ICT devices varied widely, particularly with regards to desktop and laptop PCs. The Factor 10 Visions study used an estimate for a desktop PC of 9000MJ per PC, producing 863Kg CO<sub>2</sub> emissions. There are other recent estimates of 6400MJ/260Kg CO<sub>2</sub> (Williams, 2004) and 5820MJ/640Kg CO<sub>2</sub> that show energy impacts have reduced (Lawrence Berkeley National Laboratory, 2005). We chose to use the mean of this data, resulting in figures of 7073MJ and 588Kg CO<sub>2</sub> per desktop PC.

The most recent data available for the embodied energy of a laptop PC estimated the energy consumption as between 3010-4340MJ, and CO<sub>2</sub> emissions between 227-270Kg (Deng *et al.*, 2011). SusTEACH applied a midpoint of these values (3675MJ/249Kg CO<sub>2</sub>).

It proved difficult to obtain any embodied energy data for Tablet devices. Apple currently provides no details of the lifecycle energy consumption of Tablet devices. We therefore had to estimate these impacts from a number of sources. The lifecycle emissions for an iPad are estimated at 105Kg CO<sub>2</sub> (Apple, 2011a). Tablet PCs typically have a 7 to 12 inch display so it is also useful to consider Apple's estimates of the lifecycle emissions of an 11 inch MacBook Air which are estimated at 270Kg CO<sub>2</sub>. The majority of Tablet devices are ultra-portable and comparable to the iPad in design, for example

they lack a keyboard and other peripheral devices. Taking the iPad and MacBook Air data into consideration, lifecycle emissions were estimated using the conservative figure of 150Kg of CO<sub>2</sub> per Tablet device.

The energy consumption of a Tablet device is also more difficult to estimate due to the lack of data available for this new technology. We estimated that the lifecycle energy consumption of a laptop was 3675MJ and assuming a laptop weight of 3Kg, this equates to 1225MJ/Kg. An iPad weighs 0.6Kg (Apple, 2011b see <http://www.apple.com/au/ipad/specs/>), so an estimation of the lifecycle energy consumption for this type of device is 735MJ. The iPad and similar Tablets use less energy than a conventional laptop whilst in use so this figure was revised down to an estimate of 600MJ.

Data for the embodied energy of other portable devices was calculated from a number of sources using generic figures for a mobile phone, an iPod Classic, and different e-readers. The WattzOn web-based online tool lists the embodied energy for a generic mobile phone as 424MJ per phone, 789MJ for an Apple iPhone, and 34MJ for an Apple iPod Classic. Apple further estimates the lifecycle emissions for an iPhone as 45Kg CO<sub>2</sub> per phone, and for an iPod Classic as 23Kg CO<sub>2</sub> (Apple, 2011c).

For estimating the energy impacts of e-readers, a study comparing an e-reader with printed books (Kozak, 2003) estimated the lifecycle energy consumption of the e-reader to be 742MJ, producing emissions of 50Kg CO<sub>2</sub>. This in-depth study estimated that the e-reader has an equivalent impact to the lifecycle of 40 books over 4 years. In the Cleantech (2009) report of the environmental impact of Amazon's Kindle, they estimated the lifetime emissions to be higher than Kozak at 168Kg CO<sub>2</sub>, though their figure was produced using a lifecycle analysis calculator during a short test.

Due to the variation in lifecycle energy and emissions data for portable technology, and some uncertainty about which particular portable devices respondents would be using, we settled on a lifecycle estimate of 100MJ per device, and 75Kg CO<sub>2</sub>. This assumes that the primary portable device being used is equivalent to an MP3 player.

A separate factor to consider is the potential lifespan of ICT devices as in most situations this will be longer than the length of the module. Following the Factor 10 Visions project, it was assumed on the basis of computer replacement cycles that a computer used for study would last for 3 years, which is equivalent to 3 years full time study or 360 CATS credits. The proportion of embodied energy for each ICT device that is attributable to the course or module is calculated by weighting this figure against the number of total CATS credits of the course or module. For example, a 30 credit course or module would be weighted as 30/360 CATS.<sup>11</sup> The formula for calculating the impacts of purchased ICTs follows:

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<sup>11</sup> The average OU student might typically take 6 years to complete a degree, which raised the question of whether they will need to replace their ICT equipment before attaining the degree and if an assumed 3 year/360 CATS credit lifespan is suitable for OU students. In the online prospectus, the OU advise students currently that a computer purchased since 2005 should be suitable for study in 2011. This would imply that ICT purchase impacts may be apportioned in a similar way for distance-taught students.

(Frequency of purchasing ICT equipment/ No. of students) x (CAT credits per course or module/ Total degree CATS credits) x (10 CATS credits/ course or module CATS credits).

**Table 3 Embodied energy of ICT devices**

ICT device	Lifecycle energy (MJ) per 10 CATS credits	Lifecycle CO <sub>2</sub> emissions (Kg) per 10 CATS credits
Desktop PC	196	16.3
Laptop PC	102	6.9
Tablet device	20	4.2
Other portable technologies	2.8	2.1

#### Data collection and assessment of Paper and Printed materials

Questionnaires were designed to ask students and staff to report the number of sheets of paper used in a typical week for tasks and their purchases of books and other publications associated with the course or module. Paper and print data was converted into average energy consumption and CO<sub>2</sub> per student, using carbon conversion data associated with consuming paper and print and expressed per 10 CATS credits.

#### Paper, Printed materials and CO<sub>2</sub> emissions

Students were asked to estimate how much *paper* they normally use in a typical week for printing and photocopying for the module or course. Pilot interviews revealed that there may not be a typical week for some very short modules/courses, so information was requested for one average week. Lecturers were also asked to estimate how much paper they normally use in a typical week for preparation, administration, teaching and tutoring on the module or course, including for student hand-outs, photocopying and printing. The formula for calculating the amount of paper used during a course or module follows:

(Amount of paper) x (frequency)/No. of students) x (duration of course or module) x (10 CATS credits/ module CATS credits).

The main measure used for assessing the impacts of paper and printed materials was based on embodied energy and lifetime impacts for each type of paper. The main source used was The Environmental Paper Network's (EPN) Paper Calculator, which was developed using a model by the Environmental Defence Fund (EDF) and based on findings from comprehensive research by the United States (US) based Paper Task Force (EPN, 2011). We modelled types of paper using the EPN calculator assuming a proportional use of recycled material, based on findings in 2006 that 37% of fibre used to make new paper products in the US came from recycled sources (Paperrecycles.org, 2007).

The first type of paper examined was copy paper suitable for both printing and general use. 1 tonne of copy paper consumed 28,000,000 BTUs, and produced 5051 pounds CO<sub>2</sub>, which is equivalent to 29.54MJ and 2.29Kg CO<sub>2</sub> per Kg<sup>12</sup>. The Factor 10 Visions project weighed some office paper and

<sup>12</sup> 1lb = 0.453592Kg and 1000BTUs= 0.2930710701kWh. 5051 pounds of CO<sub>2</sub> per tonne = 2291Kg CO<sub>2</sub> per tonne = 2.29Kg CO<sub>2</sub> per Kg. 28,000,000 BTUs per tonne = 8206kWh per tonne = 8.206 kWh per Kg = 29.54MJ per Kg.

found that there were approximately 200 sheets per Kg therefore the energy consumption per sheet is 0.1477MJ, and the CO<sub>2</sub> emissions are 0.0115Kg.

Students and lecturers were also asked about the number of *books, reports, newspapers and magazines* they had purchased mainly for the course or module. The formula for calculating print consumption follows:

(Total books and other publications/ No. of students) x (10 CATS credits/ course or module CATS credits).

The Environmental Paper Network Paper Calculator was again used to calculate energy and emissions for newspaper and magazine consumption, again using an estimated 37% recyclable content of paper. The lifetime environmental impact of 1 tonne of magazine paper was very similar to copy paper at 28,000,000 BTUs producing 5658 pounds of CO<sub>2</sub> emissions, or 29.54MJ per Kg and 2.566Kg CO<sub>2</sub> per Kg<sup>13</sup>.

There were different estimations for the average weight of a *magazine*. The Factor 10 Visions project weighed a selection of printed items and found that a glossy magazine had an average weight of 0.3Kg. We considered that most student purchases of magazine type publications will be academic journals which are likely to be thinner than a typical 0.30Kg glossy magazine. A recently published Finnish study (VTT, 2010) of the carbon footprint of a magazine estimated the typical 56 page Finnish weekly magazine weight to be 0.17Kg, producing lower emissions of 0.15Kg CO<sub>2</sub> per magazine (VTT, 2010). Another study reported that the 'Discovery' magazine produced higher lifecycle emissions of 0.95Kg CO<sub>2</sub> per copy, although the magazine weight is not provided (Cleantech Group, 2009), although it is likely to be greater than the VTT study's estimate. Taking account of these sources we settled on an average magazine weight of 0.25Kg. This equates to lifecycle energy and emissions figures of 7.39MJ and 0.64Kg CO<sub>2</sub> per magazine, using the figures provided by the Paper Calculator.

For *newsprint*, the Paper Calculator produces identical figures to magazines for energy consumption at 29.54MJ per Kg, and slightly lower CO<sub>2</sub> emissions of 2.497Kg CO<sub>2</sub> per Kg of paper. The VTT Finnish study estimates that a typical newspaper weight is 0.21Kg (VTT, 2010). This compares with the typical newspaper weight assumed by the Factor 10 project of 0.25Kg for a broadsheet newspaper. As newspapers are typically produced in the smaller Berliner or tabloid size in the UK, rather than as broadsheets we estimated a typical newspaper weight of 0.20Kg. This produces figures of 5.908MJ and 0.499Kg CO<sub>2</sub> per newspaper. By comparison Cleantech (2009) report that each Kg of newspaper produces 2.66Kg of CO<sub>2</sub>, which gives a very similar value of 0.53Kg of CO<sub>2</sub> for a newspaper of 0.20Kg. The SusTEACH survey asked students and staff about the purchase of *other publications* as well. An average for these has been used to convert purchases to environmental impacts rather than categorising newspapers and magazines separately<sup>14</sup>.

Students and staff were also asked about the number of *books* they had purchased for their study or teaching. The Kozak (2003) study compared the environmental impacts of an e-reader and printed books and found the lifecycle energy consumption of an academic book to be 94.85MJ, producing CO<sub>2</sub> emissions of 5.45Kg. A book was defined as 500 pages which may be slightly larger than average.

<sup>13</sup> 5658 pounds CO<sub>2</sub> per tonne = 2566Kg CO<sub>2</sub> per ton = 2.566Kg CO<sub>2</sub> per Kg

<sup>14</sup> (5.91 + 7.39) / 2 = 6.65MJ per publication, (0.499 + 0.642) / 2 = 0.571Kg CO<sub>2</sub> per publication



This study also conducted a sensitivity analysis for a book of 250 pages and found that the energy consumption was 69.05MJ and CO<sub>2</sub> emissions 3.63Kg (Kozak, 2003). The SusTEACH project assumed a book length of 375 pages, and therefore used a midpoint of Kozak's values, producing figures of 81.95MJ and 4.54Kg CO<sub>2</sub> per book.

There are some varied figures on the energy impacts of books. The Green Press Initiative (2008) found a similar CO<sub>2</sub> emissions value of 4.01Kg CO<sub>2</sub> per book, whereas the Cleantech (2009) report gives a much higher value of 7.46Kg CO<sub>2</sub> per book. The Cleantech figure was derived from three independent sources, although at least two used lifecycle calculators rather than undertaking their own lifecycle assessment. We decided to use the energy and emissions data from the Kozak study because this data was derived from the most detailed assessment study. [Sensitivity studies showed that the variations in data on book CO<sub>2</sub> emissions data made little difference to overall course/module assessments.]

**Table 4 Embodied energy of paper and printed materials**

	Energy consumption (MJ) per sheet	CO <sub>2</sub> emissions (Kg) per sheet
<b>Paper</b>	0.1477	0.0115
	Energy consumption (MJ) per item	CO <sub>2</sub> emissions (Kg) per item
<b>Book</b>	81.95	4.54
<b>Other periodicals</b>	6.65	0.57

### Teaching materials and CO<sub>2</sub> emissions

In addition to the students' use of paper and purchase of books and other publications, universities may also provide teaching materials to students, particularly distance teaching providers like The Open University. It was therefore necessary to consider what type of material was being provided and the environmental impacts of production and transportation.

The OU's distribution warehouse provided an inventory of materials provided to students for each module and the total weight of these materials. Most of the material provided is printed matter although some modules also provide content on a CD/DVD. The paper-based content can include a mix of books, study guides or booklets, and some paper, though this blend varies by module. Students are normally expected to purchase any set books themselves, so these are not included in the mailing contents. To calculate the energy consumption and CO<sub>2</sub> emissions involved with the content of materials provided by the OU we used the conversion factors for copy paper (see Paper, Printed materials and CO<sub>2</sub> emissions). This may produce an underestimation if books are included in the mailed materials, but as this is not usually the case, it provides a simple and standardised measure based on the weight of materials<sup>15</sup>.

The weight of any CD/DVD content also needed to be calculated. The average weight of a DVD, including the sleeve and standard case is estimated at 93 grams (eLivermore.com, 2011). A number of sources provided figures for the energy consumption and CO<sub>2</sub> emissions associated with the

<sup>15</sup> An alternative approach, based on the inventory of the actual printed content was considered but considered too complex. It would require several calculations and the weight of each item may not be known.



manufacturing and packaging of a CD/DVD. Figures from NewsCorp estimate 0.33Kg of CO<sub>2</sub> per DVD (reported by Veratique, 2009). Disney (2007) estimated a higher figure of 0.77Kg of CO<sub>2</sub> per DVD, although this includes delivery to stores. The Stanford University study estimated that CD production produces emissions of 0.62Kg of CO<sub>2</sub> (Weber *et al.*, 2009), and a further study estimated CD production created 0.61Kg of CO<sub>2</sub> (Julies Bicycle, 2010). Taking an average produces a figure of 0.58Kg CO<sub>2</sub> per CD/DVD (including the case).

The Stanford University study also provides data for the energy consumption involved with the production process which was found to be 15.3MJ per disk. The only other source of data was the WattzOn website which gave a higher figure of 29.39MJ (WattzOn, 2011). The Wattzon website presented little information on its sources, so we opted to use the Stanford figure of 15.3MJ per disk (Weber *et al.*, 2009).

### Transportation of teaching materials and CO<sub>2</sub> emissions

It is important to include the energy impacts associated with the transportation of teaching materials, particularly for distance teaching providers, who have typically relied on postal services. Parcel weight and its transportation are two factors in the calculation of energy and emissions.

DHL report that each parcel they deliver produces on average 500 grams CO<sub>2</sub> emissions per parcel, although they provided no data on the average parcel weight (Deutsche Post DHL, 2011). Based on an assumed average parcel weight of 1Kg the CO<sub>2</sub> emissions per parcel would be 0.5Kg CO<sub>2</sub> per Kg of parcel.

As parcels usually include more than simply paper we needed to compare this estimate with the energy impacts of letter mail. A study of the environmental impact of mail (Pitney Bowes, 2008) considered a number of sources and found that the CO<sub>2</sub> emissions per item of letter mail was approximately 0.025Kg CO<sub>2</sub> per letter, although again there was no reference to the average letter weight. Royal mail guidance indicates that a standard small (A5) letter would have a maximum weight of 100 grams. To estimate weight more exactly, we noted that a first class stamp in the USA can be used for mail suitable for personal correspondence, bills, and light merchandise that weighs less than 1 ounce (1 ounce = 28.335 grams) (USPS, 2011). If we assume an average letter weight of 30 grams and CO<sub>2</sub> emissions of 0.025Kg per letter, then the CO<sub>2</sub> emissions per Kg of mail are 0.83Kg (1000 / 30 x 0.025 = 0.83Kg CO<sub>2</sub> per Kg of mail).

Compared with the Factor 10 project's lower estimates of 0.31Kg CO<sub>2</sub> per Kg of mail, which was taken from a Dutch lifecycle analysis, these new estimates for parcel weight suggest a much higher carbon impact. The Factor 10 project estimate was derived from a post office calculation of 31.35Kg CO<sub>2</sub>/1000 items, which included letters and parcels and an assumed average item weight of 0.1Kg. We considered it more appropriate to use the DHL parcel-only data for calculating the carbon emissions of distance teaching materials, based on 0.5Kg CO<sub>2</sub> per Kg of parcel and average parcel weight estimated at 1Kg.

It was not possible to obtain any information for the energy used for the transportation of mail from either DHL or the Post Office. A US life cycle analysis of ground shipping of the US Postal Service (Mangmeechai & Matthews, 2007) found that the energy consumption per parcel in 2005 was 3,210

BTUs per parcel, which converts to 3.39MJ (based on 1000 BTU = 1.055MJ ) and CO<sub>2</sub> emissions of 0.386Kg CO<sub>2</sub> per parcel (or per Kg based on the assumed parcel weight estimate of 1Kg).

A further estimate from a guide to sustainable living (Vale, 2009) calculated a figure of 1.12MJ energy consumed per parcel to deliver items purchased online. A parcel was assumed to weigh 2Kg, and to travel 200km using lorry freight transport. This results in transportation energy consumption of 0.56MJ per Kg. This is significantly lower than the US Postal Service energy consumption data and the estimate used by the Factor 10 project of 9MJ per Kg.

With such variation in the estimates, we chose to use US Postal Service data as an indicator of the energy consumption involved with transporting 1Kg of parcel as the most comprehensive study. We took an average of the US Postal Service data and DHL's figures to estimate CO<sub>2</sub> emissions. The SusTEACH project gathered data on teaching materials mailed per course or module, (including DVDs, CDs, and paper books and booklets) and calculated the energy consumption, based on 3.39MJ per Kg, and CO<sub>2</sub> emissions calculated at 0.443Kg CO<sub>2</sub> per kilograms of parcel posted, and expressed this average impact per student per 10 CATS credits.

### **Modelling the impacts of residential energy consumption**

We did not wish to overload questionnaires with detailed questions about the buildings used for student residential accommodation. We therefore decided to combine data obtained from questionnaires with data accessed from databases to be able to model and estimate the impacts of HE courses and modules associated with residential accommodation and home energy consumption.

To identify the residential energy consumption that is attributable to courses/modules, we first identified the numbers of students who lived in the following types of residences, during the term/semester (via the student questionnaires):

- university accommodation or college hall of residence;
- flats, houses and lodgings;
- their main, usual or permanent home.

Given the proportion of students in each residential accommodation group per course or module, we estimated the average energy consumption for each group, and then calculated a weighted average per student per 10 CATS credits. For students living away from home during term-time/semester we took account of their total residential energy use as student accommodation was arguably an intrinsic part of studying full-time (Roy *et al.*, 2005).

We accessed appropriate data sources including HESA and other UK databases to estimate *university residential energy consumption* per student (FTE) from the data on residential building energy consumption and residential places available for students. As we found that some students, especially part-time students, may also use temporary accommodation on occasions for overnight or short stays we also calculated the impacts of temporary student accommodation from data on university halls of residence which function in a similar way to a hotel, in terms of the facilities and operations.

For *non-university accommodation* we gathered data from the English House Condition Survey which provides estimates on overall dwelling energy consumption data. [We also used the National Home Energy Rating (NHER) modelling software to identify the energy consumption and carbon impacts of typical UK dwellings, based on using specific heating systems and fuels, to heat and light dwellings.]

For students *studying from home* and lecturers working from home, the questionnaires were designed to identify any additional hours of heating, printing and lighting required for study or teaching that was above normal usage. The National Home Energy Rating (NHER) Surveyor software was used for calculating the home energy consumption and carbon impacts of these additional study hours.

The following formula was applied:

(Total average additional time per heating system/No. of students) x Heating Season Factor (i.e. the proportion of time this heating is required based on the number of days in a degree programme, judged to be 0.6) x (duration of course or module) x (10 CATS credits /course or module CATS credits).

The number of additional hours of printing and lighting required for study and teaching was also identified. The formula is as follows:

(Total additional time per kWh per appliance/No. of students) x (duration of course or module) x (10 CATS credits /course or module CATS credits).

### Energy use in university residences and CO<sub>2</sub> emissions

For students living in university residences, information about the energy consumption of residential buildings at each university is available from HESA's Estate Management Statistics. Though this data shows the proportion of FT students living in each type of accommodation, it does not include details of the number of residential places available which makes it difficult to apportion these figures per student. Furthermore, the residential buildings figures may exclude buildings used for secondary purposes other than accommodation.

Instead of using the HESA figures, which could have been combined with information from university accommodation officers and divided by the number of residential places available, we referred to data from four English Universities, via their publically available carbon management plans, to provide more detailed information about the energy consumption of campus residential buildings.<sup>16</sup> We calculated the mean annual energy consumption per student per room as 26644MJ. The average CO<sub>2</sub> emissions were 1615Kg CO<sub>2</sub> per student per room. Assuming a 30 week heating season and 120

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<sup>16</sup> Sources: Nottingham University (<http://www.nottingham.ac.uk/about/documents/carbonmanagementplan2011.pdf>), De Montfort University ([http://dmu.ac.uk/Images/De%20Montfort%20University%20Carbon%20Management%20Plan%20BoG1\\_tcm6-71752.pdf](http://dmu.ac.uk/Images/De%20Montfort%20University%20Carbon%20Management%20Plan%20BoG1_tcm6-71752.pdf)), Brighton University (<http://staffcentral.brighton.ac.uk/estateandfacilities/pdf-docs/Carbon-management-plan.pdf>), Personal Communication with Loughborough University.

credits of study during this period, these figures equate to 1281MJ per student per 10 CATS credits and 78Kg CO<sub>2</sub> per student per 10 CATS credits<sup>17</sup>.

### Temporary accommodation and CO<sub>2</sub> emissions

Some students may use hotel or other temporary accommodation on occasions. This is most likely to occur for part-time or distance-taught students who make infrequent trips to the university campus or regional education centres for example to attend a residential school or a week-long intensive module. University halls of residence function in a similar way to a hotel so this was taken as the base for this calculation. We calculated the impacts of this type of accommodation per room per night. The annual energy consumption for a room in halls of residence is 26644MJ, producing 1615Kg of CO<sub>2</sub> emissions. Assuming a 30 week academic year these figures equate to 888.13MJ per week or 126.88MJ per day, producing CO<sub>2</sub> emissions of 53.83Kg a week or 7.69Kg per day<sup>18</sup>. This may be an overestimation given that halls of residence may be used outside of the academic year, either by students choosing to stay in halls or when halls are used for other purposes during the summer months.

### Non-university accommodation and CO<sub>2</sub> emissions

For students living in non-university accommodation (shared housing, flats, etc.) we used the English Housing Surveys 2009, Housing Stock Report which provides details of the average annual energy consumption and emissions data for dwellings based on their heating system and fuel type (Communities and Local Government, 2011). The average annual energy use for UK dwellings is reported as 375kWh/m<sup>2</sup>. As the average dwelling size is 91m<sup>2</sup>, the average energy consumption is calculated as 34125kWh per dwelling with CO<sub>2</sub> emissions at 6 tonnes/per year.

It was assumed that for students living in shared accommodation the occupancy will be 3 persons per dwelling rather than the 2007-2008 English dwelling average of 2.4 (Communities and Local Government, 2009), and that the accommodation will be used for a typical 30 week Undergraduate academic year, equivalent to 120 CATS credits of study or a 45 week post-graduate year, equivalent to 180 credits. Both programmes have a ratio of 4 CATS credits per week which produces a figure of 1969MJ per student per 10 CATS credits and 96Kg CO<sub>2</sub> per student per 10 CATS credits<sup>19</sup>.

These conversion factors can be used for non-university student accommodation, however as they are calculated from *all* energy use per dwelling rather than just for space heating from a specific heating source, another method is required to calculate energy consumption and CO<sub>2</sub> emissions for each additional hour using a specific type of heating system by students living at their normal home address during their studies.

### Additional home energy consumption and CO<sub>2</sub> emissions

The National Home Energy Rating (NHER) Surveyor software was used to obtain this data in conjunction with some further information from the English Housing Survey Stock Report to

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<sup>17</sup> Energy:  $(26644 \times (30/52)) / (120/10)$  CO<sub>2</sub> emissions:  $(1615 \times (30/52)) / (120/10)$

<sup>18</sup>  $(26644/30)/7 = 126.88$ ,  $(1615/30)/7 = 7.69$

<sup>19</sup> Energy:  $34125 / 3 = 11375\text{kWh}$  (assumed occupancy).  $11375 / (52/30) = 6562.5\text{kWh}$  (heating season).  $6562.5 / 12 = 546.875\text{kWh} = 1968.75\text{MJ}$  (average per 10 CATS credits)  
Emissions:  $6000 / 3 = 2000\text{Kg CO}_2$        $2000 / (52/30) = 1153.85\text{Kg CO}_2$        $1153.85 / 12 = 96.15\text{Kg CO}_2$

determine the characteristics of a typical dwelling that could be modelled using the software<sup>20</sup>. This modelling tool was useful for calculating energy consumption for 'typical' dwellings and for checking the English Housing Stock Report figures, which are broadly consistent. The floor space was modelled at 91m<sup>2</sup> and the household occupancy at 3 persons. The dwelling was modelled as a semi-detached property, built between 1950 and 1965<sup>21</sup>. The dwelling was based on a location in the Midlands and assumed to have double-glazing in common with 73% of dwellings in 2009. All other variables were left as standard in the software including a heating pattern of 9 hours during weekdays and 16 hours at weekends.

The Surveyor software provided information for the CO<sub>2</sub> emissions of different fuel sources, but to improve the accuracy of the data the most recent 2011 Defra/DECC conversion factors were used to calculate CO<sub>2</sub> emissions from the energy consumption figures. For each source of heating, the space heating energy consumption arising from the standard heating pattern described above was recorded, and then a separate figure was calculated after the heating was increased for 1 hour per day. It was assumed that the heating season was 7 months, so the increase in annual space heating energy consumption resulting from an additional hour of heating was divided by 213 days (7 months) to obtain a figure for a single additional hour.

The main source of additional heating was gas central heating for which an additional hour of heating consumed between 11.78 and 15.68MJ of energy (depending on the type of boiler) and produced between 0.67 and 0.89Kg CO<sub>2</sub> emissions. The SusTEACH survey results indicated that the only other common sources of heating were room heaters. Energy consumption figures for room heaters were obtained from the Factor 10 Visions project and it was assumed that: for an electric room heater 2kWh was being used (7.2MJ per hour), producing 0.96Kg CO<sub>2</sub> per hour; for a gas room heater a maximum heat input of 6kWh (21.6MJ) MJ was assumed, producing emissions of 1.22Kg CO<sub>2</sub>.

The only other forms of heating for which it was not possible to use the Surveyor software were for heating supplied from a heat pump system and biomass heating. To determine the energy consumption for central heating from a heat pump system data was obtained from the Heat Pump Trial monitoring report (Energy Saving Trust, 2005). For Biomass heating figures were taken from The Log Pile Website and the Biomass Energy Centre (2011).

**Table 5 Additional heating energy and CO<sub>2</sub> emissions**

	Energy consumption (MJ) per hour	CO <sub>2</sub> emissions (Kg) per hour
<b>Standard/regular</b>	15.68	0.89

<sup>20</sup> The National Home Energy Rating (NHER) Surveyor software may be used to generate energy consumption information for a range of 'typical' UK dwellings, matched by size and age, and modelled on the typical characteristics that affect space heating energy, such as the boiler efficiency, occupancy, and heating controls. The surveyor software assumes that a 'typical' dwelling is gas-heated and urban. As we had not gathered data on dwelling characteristics we opted to use the 'typical' dwelling for modelling. Typical dwellings heated by oil or storage heaters are older, larger and more rural than a 'typical' dwelling, and would therefore have a higher energy consumption.

<sup>21</sup> The English Housing Stock Report indicated that 41% of dwellings were built between 1945 and 1980, 21% before 1919, and 12% after 1990. 72% of dwellings were terraced, semi-detached or detached. Only 26% of dwellings were semi-detached, however as this represents a mid-point of the 3 most common types of dwelling this was used.

<b>mains gas boiler</b>		
<b>Combination mains gas boiler</b>	15.4	0.87
<b>Condensing mains gas boiler</b>	11.78	0.67
<b>Oil boiler</b>	16.24	1.28
<b>Solid fuel boiler</b>	13.52	1.17
<b>Heat pump system</b>	28170 (per year)	3771.00 (per year)
<b>Electric room heater</b>	7.2	0.96
<b>Mains gas fire room heater</b>	21.6	1.22
<b>LPG bottled gas</b>	10.8	0.69
<b>Closed biomass or wood fuel heater</b>	6.62	0.19
<b>Open solid fuel heater (secondary heating)</b>	2.77	0.24

### Home energy consumption for printing and CO<sub>2</sub> emissions

We gathered information on student consumption of paper for printing on the course or module and staff were additionally questioned about how long they used a printer each week. The SusteIT Footprinting tool provided the conversion factors for the use of a range of printers. For SusTEACH, we also calculated estimations of generic printing speed figures for each type of printer. The energy impacts associated with additional hours of printing were calculated from data gathered on the printer type and speed relative to the number of pages printed or number of hours printing.

Manufacturers typically provide information for the maximum printing speed of different printers in *pages per minute* (ppm) or *images per minute* (ipm). This may not represent real-life conditions as print speed testing is normally in draft mode, (see Tables 6-8).

**Table 6 Inkjet printer speeds (pages per minute)**

	Print speed black text (ppm)	Print speed colour text (ppm)
Epson Stylus S22	Up to 28	Up to 15
HP Deskjet 3000	Up to 20	Up to 16
Epson Stylus SX218	Up to 34	Up to 15
PIXMA iP2700	7	4.8
PIXMA iP3600	7.3	5.5
HP Deskjet 1000	Up to 16	Up to 12
<b>AVERAGE</b>	<b>Up to 22</b>	<b>Up to 11</b>

*Note:* data obtained from manufacturers' websites

**Table 7 Mono-Laser printer speeds (pages per minute)**

	Print speed black text (ppm)
Samsung ML-1660	Up to 16
Canon i-SENSYS LBP6000	Up to 18
HP LaserJet Pro P1102	Up to 18
HP LaserJet Pro P1566	Up to 22
<b>AVERAGE</b>	<b>Up to 19</b>

*Note:* data obtained from manufacturers' websites

Table 7 shows that the printing speed for laser printers was broadly similar across different manufacturers. An assumption is made that students will typically be printing black text, however referring to Table 6 we used an estimate of 15ppm as the printing speed, to allow for a mix of low and higher quality printing.

Using the SustelT Footprinting tool we were able to calculate the energy impacts and carbon conversions for the printers used (Table 8). Printers may be switched on but left inactive but this impact would not be specifically attributable to courses/modules as printers are used for other functions.

**Table 8 Printer energy consumption**

	Energy consumption (MJ) per hour	CO <sub>2</sub> emissions (Kg) per hour
Inkjet printer	0.072	0.01
Mono-laser printer	1.26	0.17
Laser mdf	1.8	0.241

### Home energy consumption for lighting and CO<sub>2</sub> emissions

We considered the impact of lighting for completeness, although Table 9 shows that the associated energy consumption and CO<sub>2</sub> emissions had a relatively minimal impact.

**Table 9 Lighting energy consumption (based on 2 lights in use)**

	Energy consumption (MJ) per hour	CO <sub>2</sub> emissions (Kg) per hour
Low energy lighting (11 Watts)	0.079	0.011
Lighting (35 Watts)	0.252	0.033
Lighting (60 Watts)	1.8	0.058

### Campus site energy consumption and CO<sub>2</sub> emissions

The energy and emissions arising from the provision of residential campus accommodation for students has already been considered. The main campus energy consumption and emissions considered is associated with the use of non-residential campus accommodation for teaching purposes in UK HE institutions.

Annual non-residential energy consumption and emissions data for each University can be obtained from the Estates Management Statistics returned on an annual basis to HESA, but the figures include the energy consumed not just for teaching, but also for other non-residential University campus activities such as research<sup>22</sup>. To provide a measure of the total non-residential energy consumption and CO<sub>2</sub> emissions that were attributable to teaching, we referred to HE funding information for 2009/2010 from the Higher Education Funding Councils for England (HEFCE) and Wales (HEFCW) and the Scottish Funding Council (SFC), which provides details of funding for both teaching and total funding for HE institutions<sup>23</sup>. The average proportion of total UK funding that was allocated to teaching across all higher education institutions was 72 % (Table 10), which we could apply to provide the overall UK average campus energy consumption attributable to teaching (HESA, 2010)<sup>24</sup>.

The non-residential campus energy consumption and CO<sub>2</sub> emissions attributable to teaching (presented in Table 11) were then divided by the total number of full-time equivalent (FTE) students at UK Universities (excluding Northern Ireland)<sup>25</sup> (Table 10) and then multiplied by 10/120 to produce a figure per student per 10 CATS credits (Table 12). In summary, the formula for calculating non-residential campus energy consumption and CO<sub>2</sub> emissions per UK student per 10 CATS credits is: 72% non-residential campus energy and CO<sub>2</sub>/number of FTE students x 10/120 credits (where full-time study is equivalent to taking 120 CATS credits per academic year).

<sup>22</sup> Estates Management Statistics data 2009/2010,  
[http://www.hesa.ac.uk/index.php?option=com\\_content&task=view&id=2093&Itemid=239](http://www.hesa.ac.uk/index.php?option=com_content&task=view&id=2093&Itemid=239).  
HESA Estate Management statistics for 2010/2011 will not be available until summer 2012.

<sup>23</sup> Total funding for English Higher Education Institutions 2009-10,  
[http://www.timeshighereducation.co.uk/Journals/THE/THE/5\\_March\\_2009/attachments/Charts.pdf](http://www.timeshighereducation.co.uk/Journals/THE/THE/5_March_2009/attachments/Charts.pdf)

Scottish Funding Council Facts & Figures,

[http://www.sfc.ac.uk/web/FILES/ReportsandPublications/Facts\\_and\\_Figures\\_2010.pdf](http://www.sfc.ac.uk/web/FILES/ReportsandPublications/Facts_and_Figures_2010.pdf)

HEFCW Recurrent Funding Allocations 2009/10

[http://www.hefcw.ac.uk/documents/publications/circulars/circulars\\_2010/W10%2028HE%20Regional%20strategies%20for%20the%20planning%20and%20delivery%20of%20HE%20-%20Funding%20and%20support%20-%20Annex%20H-J.pdf](http://www.hefcw.ac.uk/documents/publications/circulars/circulars_2010/W10%2028HE%20Regional%20strategies%20for%20the%20planning%20and%20delivery%20of%20HE%20-%20Funding%20and%20support%20-%20Annex%20H-J.pdf)

<sup>24</sup> There is a question about how accurately the funding figures could represent the allocation of energy consumption to HE teaching functions. For example, in England the withdrawal of HEFCE funding for students working towards Equivalent or Lower Qualification (ELQ) in 2009-10 means not all HE student (FTE) places receive funding. [www.hefce.ac.uk/faq/elq.htm#](http://www.hefce.ac.uk/faq/elq.htm#)

<sup>25</sup> Student FTE Teaching Total' figures from the Estates Management Statistics data 2009/2010,  
[http://www.hesa.ac.uk/index.php?option=com\\_content&task=view&id=2093&Itemid=239](http://www.hesa.ac.uk/index.php?option=com_content&task=view&id=2093&Itemid=239)



Tables 10 to 12 details this process and produces final figures for the average non-residential energy consumption and CO<sub>2</sub> emissions as 825.74MJ per student per 10 CATS credits, and 76.69kg CO<sub>2</sub> per student per 10 CATS credits.

**Table 10 UK HE funding and FTE students**

	UK HE teaching funding 2009/2010 (£000) [Note 23]	Total funding for HE 2009/2010 (£000) [Note 23]	% of funding for teaching purposes [Note 23]	Number of FTE students [Note 25]
<b>All UK institutions (excluding NI)</b>	5509331	7634770	72.2	1590835.9

**Table 11 HE institutions: energy and CO<sub>2</sub> emissions**

Institution	Total HEI energy consumption (kWh) 2009/2010 [Note 22]	Total HEI CO <sub>2</sub> emissions (kg) 2009/2010 [Note 22]	Non-residential energy consumption (kWh) 2009/2010 [Note 22]	Non-residential CO <sub>2</sub> emissions(kg) 2009/2010 [Note 22]
<b>All UK institutions (excluding NI)</b>	7664143644	2574797518	6081539119	2033412481

**Table 12 HE institutions non-residential energy consumption and CO<sub>2</sub> emissions**

Institution	Non-residential energy consumption (kWh) 2009/2010 attributable to teaching [1]	Non-residential CO <sub>2</sub> emissions(kg) 2009/2010 attributable to teaching [2]	Non-residential energy consumption (kWh) per student per 10 CATS credits [3]	Non-residential energy consumption (MJ) per student per 10 CATS credits	Non- residential CO <sub>2</sub> emissions (kg) per student per 10 CATS credits [4]
<b>All UK institutions (excluding NI)</b>	4378708166	1464056986	229.37	825.74	76.69

[1] Non- residential energy consumption (table 11) multiplied by HE funding apportioned to teaching (Table10)

[2] Non- residential CO<sub>2</sub> emissions (table 11) multiplied by HE funding apportioned to teaching (Table 10)

[3] Non-residential energy consumption attributable to teaching divided by number of FTE students (Table 10), divided by 12 (full time study equivalent to 120 CATS credits per year)

[4] Non-residential CO<sub>2</sub> emissions attributable to teaching divided by number of FTE students (Table 10), divided by 12 (full time study equivalent to 120 CATS credits per year)

There is considerable variation between universities in the proportion of funding for teaching purposes, the number of FTE students and campus energy consumption. As we were able to obtain HEFCE teaching funding figures for the each of the HE institutions participating in the SusTEACH project, we applied these specific figures for the carbon assessments and confidential reporting to

each institution participating in SusTEACH<sup>26</sup>. For the main analysis and development of the SusTEACH toolkit, the UK aggregates were used to calculate the average UK campus site energy consumption and CO<sub>2</sub> attributable to teaching. The aggregates for The Open University were included to exemplify the energy impacts associated with the distance teaching system.

### **Calculating course/module environment impacts and lifetime impacts**

Data obtained for each environmental impact was organised into consistent forms and normalised using CATS credits (or hours of study) to provide the average energy consumption and CO<sub>2</sub> emissions of a course or module per student per 10 CATS credits (equivalent to 100 hours of study). This allowed for comparisons of the energy impacts of different courses or modules, associated with travel, ICTs, paper and printed materials, residential energy and site energy and overall impacts.

The Open University distance teaching system differs from campus Universities as modules are prepared centrally by a module team and then delivered to students online or by post and sometimes face-to-face in regional centres with the support of tutors (Associate Lecturers). We therefore needed to account for module production and presentation impacts to support comparisons with campus-based teaching systems, as well as the transportation of teaching materials.

We surveyed students on all course or module represented in the SusTEACH project and calculated their average energy impacts. In the distance teaching system, we surveyed representative samples of Associate Lecturers on each of the modules selected for investigation, and calculated their average impacts per student based on actual tutor: student ratios (which averaged at 1:18), per 10 CATS credits.

With the campus-based lecturers, and lecturers involved with both the production and presentation at The Open University, we used the 'main academic equivalent' method which is based on surveying or interviewing on one lecturer involved with the key lecturing activities to establish their course or module related impacts. The main academic's impact is assumed to be equivalent or proportionate to the other lecturers involved, and therefore the impacts of the main academic are multiplied by the number of other lecturers involved with the course or module production or presentation process. The average main lecturer's energy consumption and CO<sub>2</sub> emissions are therefore scaled up to cover the full lecturing team and then divided by the number of students on the course or module, using the actual student numbers.

It is not always straightforward to determine the number of students studying the course or module. In the OU there can be significant dropout as a module progresses, so we defined the number of students as the number still registered after one third of the module had passed. Campus-based lecturers were able to provide student numbers participating post-registration.

There was another issue with apportioning the module production impacts per student with the calculation of overall module energy impacts. The module production phase is defined as including

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<sup>26</sup> Funding figures showed variation in the HEFCE figures for teaching. Overall average for HEFCE funding for teaching was 72% but this varied for example as follows: The OU (94%), Loughborough University (63%), Cranfield University (40%) and Oxford University (32%).

[http://www.timeshighereducation.co.uk/Journals/THE/THE/18\\_March\\_2010/attachments/THE%20p8-9.pdf](http://www.timeshighereducation.co.uk/Journals/THE/THE/18_March_2010/attachments/THE%20p8-9.pdf).

preparations for module approvals, the main production work and the module presentation to students for the first time. The planning and production of a new module in a distance education HE system usually takes about 2.5 years. To calculate the lecturers' production impacts we needed to establish: the length of time taken for module production; the course/module team size (including academics, regional staff, designers, editors and audio/video producers); and the number of days that the 'main academic' spent working on module production. To be able to apportion the production impacts per student we needed to divide the impact figures by the module lifetime period, which was usually about 8 years, and then further divide it by the expected number of students taking the module over the module lifetime, to express the impact per student per 10 CATS credits.

The production and delivery impacts of campus-based teaching are more difficult to disentangle. We noted lecturers' responses on whether the course/module was new or just required updating. As none of the campus-based courses and modules participating in the SusTEACH project were newly developed, further research would be needed to assess the environmental impacts of new educational programmes.

#### **Lifetime impacts of courses and modules**

Once all course or module impacts were combined and expressed in terms of energy consumption and CO<sub>2</sub> impacts per student per 10 CATS credits, we could consider scaling the impacts up to cover the lifetime of the module. The concept of the standard lifetime of a course/module will vary to some extent between HE institutions. The module lifetime is of particular interest to distance education providers, such as The Open University (OU) where there is a significant investment in the module production process. It is important to consider because savings on CO<sub>2</sub> emissions and economic payback is partially determined by the expected number of students participating over the module lifetime, the ratio of staff to students, as well as other characteristics of the teaching system and campus site facilities.

In the OU the module life is determined at approval and relates to the currency of educational resources. The expected standard lifetime for a module is 8 years before replacement by a new or significantly revised module; although annual updating or periodic revisions take occur more easily with the use of ICTs. As the OU is moving towards an increasingly online provision we included a calculation of the environmental and lifetime impacts of courses and modules taught mainly online.

To simply model the effects of student numbers on energy consumption and CO<sub>2</sub> the following approach may be taken: Multiply the energy consumption (in MJ) and CO<sub>2</sub> impacts (calculated per student per 10 CATS credits) by the expected number of students per year and then multiply this figure by expected years of the course or module life. This should be added to the energy impacts for the main lecturer scaled up to cover the full lecturing team, and divided by the number of students on the course or module to provide an estimation of the impacts per year, which should be then multiplied by expected years of the course or module life.

Modelling the effects of student numbers contribute to understanding the lifetime impacts of courses and modules using specific delivery methods, but more accurate modelling requires other factors to be calculated or assumed, including staff: student ratios, and the energy impacts associated with campus buildings, transport, accommodation, materials and ICT devices etc. As the

HE sector aims to achieve carbon reductions, the lifetime impacts of courses or modules should not be modelled on scenarios of no-change.

Following the environmental assessment we were then able to classify the courses or modules and consider their environmental impacts within the Teaching Models' framework, discussed in the section on *Classifying HE Teaching Models using ICTs*.

### **SusTEACH Toolkit**

The SusTEACH project aimed to develop Sustainable Tools for the Environmental Appraisal of the Carbon Impacts of Higher Education (HE) Teaching Models using ICTs. Building on the findings, we developed an environmental appraisal toolkit which is designed to support: the modelling of HE teaching carbon impacts; the planning of more sustainable courses, modules and programmes; the collection of data on the teaching, learning and assessment activities in HE; and support carbon-based assessments and carbon reduction policies and contribute towards achieving more sustainable teaching practices in HE.

***The toolkit provides a number of interactive tools and resources aimed at supporting lecturers' planning and understanding of the environmental impacts of courses and modules in Higher Education. See <http://www9.open.ac.uk/SusTeach/>***

The SusTEACH Planning and Modelling Tools were developed by modelling the energy impacts associated with specific teaching delivery methods and Teaching Models and both aim to help reduce impacts when new modules/courses and programmes are designed.

**The SusTEACH Planning Tool** helps lecturers and academic designers to rate their teaching delivery plan and produces personalised feedback on the likely environmental impacts associated with this plan. The tool uses qualitative measures to assess a proposed design or plan for teaching and learning in terms of whether it is delivered using face-to-face, online ICTs (including digital resources and learning technologies), and/or specially developed printed teaching materials within a HE teaching system. This educational tool produces a detailed report based on a comparative analysis of the environmental impacts of different teaching delivery models.

**The SusTEACH Modelling Tool** is an operational desktop tool for the lecturer and academic director which permits the modelling of one or several courses or modules within a qualification programme to estimate the energy impacts associated with different HE Teaching Models. This tool is designed to follow from the SusTEACH Planning Tool and allows more sensitive modelling of the likely carbon impacts of the teaching methods being used, and the particular the impacts associated with student travel and course or module-related purchases. As the Modelling Tool is used to model the impacts of several courses or modules, the results may be extrapolated to the level of qualification programme, which allows estimations of the impacts created by the balance of Teaching Models used in HE institutions.

The **SusTEACH Carbon Calculators** builds on the carbon conversions data gathered for the SusTEACH project and the specially developed questionnaires for staff and students. There are two calculators available which aim to help lecturers to calculate their teaching-related carbon impacts, and students to calculate their study-related carbon impacts. The carbon calculator includes carbon conversion factors to assess the impact of course or module travel, and the materials, equipment or

resources used by staff, or provided to students or that students are expected to purchase or use during their studies, including the following:

- Regular commuting and occasional travel to and from university accommodation;
- ICT equipment purchased or used in teaching and learning. e.g. Desktop Personal Computer, Laptop, Tablet device, Personal media player, Mobile phones, eBook reader;
- Energy consumption associated with time spent connecting to the Internet and the university websites;
- Specially developed teaching materials and digital resources;
- Print and paper purchase and use;
- Types of residential accommodation;
- Additional home energy consumption;
- Campus site energy consumption attributable to teaching.

The Calculators utilise updated carbon conversion factors for energy fuel sources for calculating energy consumption and carbon impacts, which are measured using information based on the study hours or CATS credits applicable to a course/module and the duration of the course/module. These Calculators offer useful research and assessment to support further data collection.

The SusTEACH Environmental Appraisal Toolkit aims to support more sustainable teaching practices. This includes maintaining the effectiveness of the pedagogic function, the achievement of educational goals and the economic success conditions for continuance, without incurring negative impacts on the global or local environment. The SusTEACH toolkit supports the modelling of key sources of energy-related Scope 1, and 2 emissions and is available to support further data gathering. It also models some sources of Scope 3 CO<sub>2</sub> emissions, such as associated with course or module-related travel and procurement. The methodology could be extended to gather data on waste or water use behaviours to further support the collection of energy and emissions data for HEFCE carbon baselines comparisons, (see [http://www.hefce.ac.uk/pubs/hefce/2010/10\\_01/](http://www.hefce.ac.uk/pubs/hefce/2010/10_01/)).

## Conclusion

This report presents the methodological steps followed to undertake the environmental impact assessment of HE courses and modules for the SusTEACH study of Higher Education Teaching Models and the use of ICTs to enhance or replace traditional teaching delivery methods. The SusTEACH Methodology is a guide to support senior management when conducting an environmental impact assessment of courses and modules in Higher Education, and to the use of the Toolkit. This builds on the SusTEACH team experience with conducting an environmental assessment and provides advice on gathering environmental impact data, measuring energy consumption and calculating carbon impacts associated with courses/modules.

This report maintains that the SusTEACH project methodology represents a valid approach to conducting an environmental assessment of diverse and complex HE Teaching Models. There were a number of methodological issues which have been made explicit in this report. The main issues include:

- A reliance on retrospective estimations of course and module related activities by students and staff;

- Difficulties assessing courses and modules with unclear boundaries in terms of study hours,
- Inter- and intra-institutional variability, as well as intra-course or module variability in teaching delivery structures;
- Variations in the carbon conversions for sources of environmental impacts.

Whilst the SusTEACH methodology arguably represents a valid approach to conducting an environmental assessment of HE courses and modules, it is not claimed that Teaching Models and specific delivery methods consistently generate the associated energy impacts and carbon emissions that we found in SusTEACH. Energy impacts are not solely related to teaching delivery methods and systems, nor are they within the control of lecturers and academic designers. The energy impacts associated with Teaching Models will also vary in response to student lifestyle, choice of residence and transport behaviours. A large study to represent the variation and complexity of HE teaching courses and modules is therefore needed to confirm SusTEACH findings.

Further changes in UK Higher Education will affect the environmental impacts of HE Teaching Models, such as the ICT-based transformation of HE Teaching Models, the further greening of university buildings as well as changes to fuel carbon factors due to the decarbonisation of the electricity grid in the UK. The SusTEACH findings should therefore be treated as indications of the carbon impacts associated with Higher Education Teaching Models.

Building on the findings, we developed an environmental appraisal toolkit which supports both the modelling of HE teaching impacts and the planning of more sustainable courses and modules. The SusTEACH Planning Tool is mainly an educational tool, although both the Planning and Modelling tools may be utilised to support carbon-based assessments in HE. We hope that the SusTEACH Environmental Appraisal Toolkit will promote greater awareness of sustainability issues in Higher Education.

### Further Resources

*Further online resources are available to support Sustainable Futures in Higher Education.*

Higher Education Environmental Performance Improvement (HEEPI) developed The Energy benchmarking Tool: CE BenchBuild. This calculates the energy performance and carbon impacts of buildings in Higher Education Institutions and makes comparisons with UK national benchmarks.

(<http://www.heepi.org.uk/benchmarking.htm>)

The People & Planet Green League offers an assessment and ranking system of the environmental and ethical policies and performance of UK universities. (<http://peopleandplanet.org/green-league-2011/table>)

Sustainability On-line Resource and Toolkit for Education (SORTED) offers guidance to senior management at Further Education Colleges on how to engage students and staff with sustainability challenges and practices using case studies to illustrate guides on Leadership & Management, Buildings and Estates, Community & Business, and Teaching & Learning.

(<http://www.eauc.org.uk/sorted/home>)

The SusteIT ICT Energy and Carbon Footprinting tool may be used to estimate energy consumption and CO<sub>2</sub> emissions associated with ICT use in Higher Education Institutions.

(<http://www.susteit.org.uk/files/category.php?catID=4>)

The Carbon Trust Case Studies on Greening Campus Buildings, present interesting studies on improving the energy efficiency of university buildings and computer rooms, and achieving carbon reductions by installing renewable and microgeneration technologies (see the Carbon Trust, Higher Education Case Studies, <http://www.carbontrust.co.uk/about-carbon-trust/case-studies/public-sector/higher-education/pages/default.aspx>)

The Greening Events Planning Toolkit helps plan academic events and includes an Academic Event Profiler tool that analyses the impacts of events (including CO<sub>2</sub> emissions and financial costs) to provide a baseline measure for carbon reduction management.

(<http://www.jisc.ac.uk/whatwedo/programmes/greeningict/organisational/events2.aspx>).

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More recent data is available  
[http://www.timeshighereducation.co.uk/Journals/THE/THE/29\\_March\\_2012/attachments/Hefce\\_funding\\_2012\\_13.pdf](http://www.timeshighereducation.co.uk/Journals/THE/THE/29_March_2012/attachments/Hefce_funding_2012_13.pdf) (Accessed 30 April 2012).

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## SUSTEACH - SAMPLE QUESTIONNAIRE FOR CAMPUS-BASED STUDENTS

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welcome - Thank you for coming to take part in this short survey

Answer the questions as accurately as you can without spending a lot of time on each item. If possible check your diary or other records when answering. Give estimates or approximate information where necessary.

PLEASE NOTE: This questionnaire uses the terms **module and course** to refer to a set of standardized, independent or interrelated teaching units that can be used to construct an educational **qualification programme** (sometimes also referred to as COURSES), such as a Bachelors, Masters or Diploma programme.

More information about SusTEACH can be found here: <http://www.open.ac.uk/blogs/susteach/>

If you encounter any problems completing the questionnaire, please email the survey team: XXX

Your responses are strictly confidential. We will not disclose any personal information in any material or analysis arising from this survey and we will not pass on your personal details to any third party.

*Data Protection Information: The data you provide will be used for research and quality improvement purposes and the raw data will be seen and processed only by The Open University staff and its agents. This project is administered under the OU's general data protection policy guidelines.*

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i2 - About you

q1 - Your University

Please select the name of your university from the following:

*(Please select one only)*

- ☐ XXX University (1), etc.  
☐ Other, please specify: (2) \_\_\_\_\_

---

q1A1 - Title of the module/course that you study

Please select the title of the module/course that you study from the following:

*If the title is not listed please specify the title in the 'Other' box below.*

*(Please select one only)*

- ☐ XX (1). etc.  
☐ Other, please specify (2) \_\_\_\_\_

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q1b - We would like you to focus on the module/course that you have selected when you respond to this questionnaire.

How are modules/courses taught on your university qualification programme?

*(Please select one only)*

- ☐ One at a time in blocks of time over the qualification programme (1)  
☐ Several modules/courses are taught in parallel each week (2) **Goto Q1b\_1**

---

q1b\_1 - How many modules/courses have you studied during the previous 3 months of term/semester?

*(Please select one only)*

- ☐ 1 (1)  
☐ 2 (2)  
☐ 3 (3)  
☐ 4 (4)  
☐ 5 (5)  
☐ 6 (6)

---

q2 - Are you:

*(Please select one response only)*

- ☐ a full-time student of this module/course? (1)  
☐ a part-time student of this module/course? (2)

---

i3 - TRAVEL FOR STUDYING Please complete the questions below for all the travelling you have done DURING A TYPICAL WEEK IN TERM-TIME TO PURSUE YOUR UNIVERSITY STUDIES.

This includes journeys made mainly for studying the module/course you have been asked to focus on, although we recognise that you may sometimes combine these journeys with trips for other studies on other modules/courses, work or shopping

---

q3 - Please indicate the number of journeys you made IN A TYPICAL WEEK for this module/course:

*(Please select one response only per statement)*

	None (1)	One (2)	Two (3)	3 to 5 (4)	6 or more (5)
To travel from your usual term-time residence to the University campus/main place of study (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To travel to other study sites (e.g. other campus sites, off-campus, field trips, non-campus libraries) (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q4 - Please indicate the TOTAL distance travelled in a TYPICAL WEEK for each type of journey associated with this module/course:

If you sometimes combine study related journeys with trips for other purposes (e.g. work or shopping) then OMIT this additional mileage from your estimate of the total distance travelled. (Note: 1 mile = 1.6km)

(Please select one response per statement to indicate the TOTAL ROUND-TRIP distance travelled)

	None (1)	Under 2 miles (2)	2 to 10 miles (3)	11 to 30 miles (4)	31 to 50 miles (5)	51 to 70 miles (6)	71 to 100 miles (7)	Over 100 miles (9)	Not applicable (10)
To travel from your usual term-time residence to the University campus/main place of study (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To travel to other study sites (e.g. other campus sites, field trips, off-campus libraries) (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q4\_over100 - If over 100 miles, please specify the number of miles and for which journey(s)

q4a - We are interested in calculating the energy impacts associated with the module/course that you selected at the beginning of this questionnaire. Does your response above apply to one module/course or several module/courses during a typical week this term/semester?

(Please select one response only)

- ☐ Selected module/course (1)  
☐ Several modules/courses this term/semester (2) **GO to 4a\_1**

q4a\_1 - We would like to estimate your travel impacts for one course/module. How many modules/courses are included in the travel information that you have given? Please specify how many modules/courses do you travel to attend in a typical week?

(Please select one only)

- ☐ 1 (1)  
☐ 2 (2)  
☐ 3 (3)  
☐ 4 (4)  
☐ 5 (5)  
☐ 6 or more (6)

q4b - Please indicate the TOTAL distance travelled during the PREVIOUS 3 MONTHS of TERM/SEMESTER to other study sites for this module/course:(e.g. other campus sites, field trips, non-campus libraries); (Note: 1 mile = 1.6 km)

(Please select one response only)

	None (1)	Under 2 miles (2)	2 to 10 miles (3)	11 to 30 miles (4)	31 to 50 miles (5)	51 to 100 miles (6)	Over 100 miles (7)	Not applicable (8)
To travel to other study sites (e.g. other campus sites, field trips, non-campus libraries) (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q5 - Please indicate the number of occasional journeys you made during the previous 3 months of TERM/SEMESTER on other journeys to pursue your study of the module/course such as:

(Please select one only per row)

	None (1)	One (2)	Two (3)	3 to 5 (4)	6 or more (5)
Journey(s) to enquire, register and prepare for studying your module/course (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Journey(s) to obtain books and Information and Communication Technologies (ICTs) (e.g. Personal computers, laptops, tablet devices, smart phones etc) (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Journey(s) to meet fellow students or others for module/course-related activities (not just to socialize) (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Any other journeys associated with your studies (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q6 - Please indicate the TOTAL DISTANCE travelled during the previous 3 months of TERM/SEMESTER for each type of journey you make occasionally as part of your studies. (1 mile = 1.6km).

If you make more than one type of journey, for example to buy books and equipment, please enter the average round trip mileage for this type of trip.

(Please select one response only per statement)

	None (1)	Under 2 miles (2)	2 to 10 miles (3)	11 to 20 miles (4)	21 to 30 miles (5)	31 to 40 miles (6)	41 to 50 miles (7)	51 to 100 miles (8)	Over 100 miles (9)	Not applicable (10)
Journey(s) to enquire, register and prepare for studying your module/course (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Journey(s) to obtain books and other module/course materials and IT equipment (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Journey(s) to meet fellow students or others for module/course-related activities (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Any other journeys associated with your studies (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



q7 - For the past 3 months of TERM/SEMESTER, how many RETURN (round trip) journeys did you make between your usual TERM TIME RESIDENCE and your usual HOME ADDRESS?

Include journeys from and to your home address at the beginning and end of each term if appropriate.

(Please select one response only)

- ☐ None (e.g. I live at my home address during term) (1)  
☐ One (2)  
☐ Two (3)  
☐ 3 to 5 (4)  
☐ 6 to 10 (5)  
☐ 11 to 12 (6)  
☐ 13 or more (7)

q8 - Please give details of travel between home and your term-time residence address below:

Typical ROUND TRIP distance between home and term-time address. (1 mile = 1.6 km)

(Please select one response only)

- ☐ Under 20 miles (1)  
☐ 21 to 100 miles (2)  
☐ 101 to 200 miles (3)  
☐ 201 to 400 miles (4)  
☐ If over 400 miles, give the approximate distance or name the location: (5) \_\_\_\_\_

q9 - Method of Transport usually or most often used:

(If more than one involved select the method used for the LONGEST part of the journey.)

(Please select one response only per statement)

	Walk (1)	Bicycle (2)	Car driver (3)	Car passenger (4)	Motorbike (5)	Bus (6)	Express coach (7)	Rail (8)	Metro,Tube,Tram (9)	Other (10)
To travel from your usual term-time residence to the University campus (Your main place of study) (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To travel to other study sites (e.g. other campus sites, off-campus, field trips, non-campus libraries) (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To travel between your home and your term-time residence address (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Walk (1)	Bicycle (2)	Car driver (3)	Car passenger (4)	Motorbike (5)	Bus (6)	Express coach (7)	Rail (8)	Metro,Tube,Tram (9)	Other (10)
Other journeys to pursue your study of the module/course (e.g. - To enquire, register and prepare for studying your module. – To obtain books materials and ICT equipment. To meet fellow students or others for module/course-related activities). (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

If Option Q9 (3) is selected **GOTO Q9a, 9b**

q9a - You indicated that you use a car for one or more of the journeys mentioned previously, what is the engine size of the vehicle usually or most often used?

(Please select one response only)

- ☐ Up to and including 1.4 litres (1400 cc) (1)  
☐ Over 1.4 and up to and including 1.6 litres (1600cc) (2)  
☐ Over 1.6 and up to and including 2 litres (2000 cc) (3)  
☐ Over 2 litres (4)  
☐ Don't know (5)

q9b - Has the car:

(Please select one response only)

- ☐ A petrol (gasoline) engine (1)  
☐ A diesel engine (2)  
☐ A battery or plug-in electric engine (3)  
☐ A hybrid petrol-electric engine (4)  
☐ A hydrogen fuel-celled engine (5)  
☐ Another form of power, please specify: (6) \_\_\_\_\_  
☐ Don't know (7)

i4 - Part B: Use of Energy and Materials for studying

We'd like to ask about your use of Information and Communication Technologies (ICTs) (e.g. Personal computers, laptops, tablet devices, smart phones etc) for study on this module.

---

q10 - What type of ICTs did you use for studying your module/course?

*(Please select all the ICT equipment that you use for learning)*

- ☐ Desktop Personal Computer (1)
- ☐ Lap-top (2)
- ☐ Tablet device (3)
- ☐ Other portable technologies e.g. personal media players, mobile phones. Please specify: (4) \_\_\_\_\_
- ☐ None (5)

*If Option Q10 (1) is selected GOTO Q10a, 10b*

---

q10a - Is your Personal Computer:

*(Please select one response only)*

- ☐ High power (uses 100 watts when active) (1)
- ☐ Medium power (uses 60 watts when active) (2)
- ☐ Low power (uses 30 watts when active) (3)
- ☐ Don't know (4)

---

q10b - What type of computer monitor did you use for your studies?

*(Please select one response only)*

- ☐ Flat (LCD or TFT) monitors [Liquid crystal display (LCD) or Thin Film Transistor liquid crystal display (TFT)] (1)
- ☐ Cathode Ray Tube (CRT) monitor (2)
- ☐ Don't know (3)

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q11 - How many hours IN A TYPICAL WEEK did you use ICTs for study and learning activities on this module/course?

*(Please select one response only)*

- ☐ 1 to 5 hours per week (under 1 hour per day) (1)
- ☐ 6 to 15 hours per week (about 1 to 2 hours per day) (2)
- ☐ 16 to 20 hours per week (about 2 to 3 hours per day) (3)
- ☐ 21 to 35 hours per week (about 3 to 5 hours per day) (4)
- ☐ 36 to 50 hours per week (about 5 to 7 hours per day) (5)
- ☐ Over 50 hours per week (over 7 hours per day) (6)
- ☐ It's left switched on 24 hrs per day, mainly for module/course-related use (7)
- ☐ Don't know (8)

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q11a - Does your previous response apply to the module/course selected at the beginning of this questionnaire or several modules/courses studied during the typical week this term/semester?

*(Please select one response only)*

- ☐ The selected module/course (1)
- ☐ Several modules/courses this term/semester (2)

q11b - Of those hours, how many hours IN A TYPICAL WEEK in total did you spend using the following ICTs for study on this module/course?

(Please select one response only per row)

	1 to 5 hours per week (under 1 hour per day) (1)	6 to 15 hours per week (about 1 to 2 hours per day) (2)	16 to 20 hours per week (about 2 to 3 hours per day) (3)	21 to 35 hours per week (about 3 to 5 hours per day) (4)	36 to 50 hours per week (about 5 to 7 hours per day) (5)	Over 50 hours per week (over 7 hours per day) (6)	Don't know (7)	Not applicable (8)
Personal Computer (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lap-top (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tablet device (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other portable technologies e.g. personal media players, mobile phones (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q12 - How many hours IN A TYPICAL WEEK did you spend USING ICTs for your studies on this module/course in the following locations?

(Please select one response only per row)

	None (1)	1 to 5 hours per week (under 1 hour per day) (2)	6 to 15 hours per week (about 1 to 2 hours per day) (3)	16 to 20 hours per week (about 2 to 3 hours per day) (4)	21 to 35 hours per week (about 3 to 5 hours per day) (5)	36 to 50 hours per week (about 5 to 7 hours per day) (6)	Over 50 hours per week (over 7 hours per day) (7)	Don't know (8)
Campus (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Home (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Term address (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Work (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In-transit e.g. on bus, train (5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q13 - How many hours IN A TYPICAL WEEK did you use ICTs for the following COMPUTING ACTIVITIES for your module/course studies?

(Please select one response only per row)

	None (1)	1 to 5 hours per week (under 1 hour per day) (2)	6 to 15 hours per week (about 1 to 2 hours per day) (3)	16 to 20 hours per week (about 2 to 3 hours per day) (4)	21 to 35 hours per week (about 3 to 5 hours per day) (5)	36 to 50 hours per week (about 5 to 7 hours per day) (6)	Over 50 hours per week (over 7 hours per day) (7)	Don't know (8)
Offline computing activity (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Connection to internet websites for learning (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Connection to university websites (e.g. virtual learning environment) (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q14 - Did you purchase any additional ICT equipment mainly in order to study this module/course?

(Please select all that apply)

- ☐ Desktop Personal Computer (1)
- ☐ Lap-top (2)
- ☐ Tablet device (3)
- ☐ Other portable technologies e.g. personal media players, mobile phones (4)
- ☐ Printer (5)
- ☐ Other hardware (e.g. modem) (6)
- ☐ Upgrades to existing hardware (e.g. extra memory) (7)
- ☐ No, I use existing equipment (8)

q15 - During THE WHOLE MODULE/COURSE approximately how many SOFTWARE PACKAGES did you BUY mainly this module/course?

(Please select one only)

- ☐ None (1)
- ☐ 1 to 2 (2)
- ☐ 3 to 4 (3)
- ☐ 5 or more (4)
- ☐ Don't know (5)

i5 - We'd next like to get an idea of how much PAPER other than the printed module/course materials you use for studying your module/course.

q16 - Please answer the following:

(Please select one response only per row)

	0 to 10 pages (1)	11 to 25 pages (2)	26 to 50 pages (3)	51 to 100 pages (4)	Over 100 pages (5)	Don't know (6)
Roughly, how much paper do you normally use IN A TYPICAL WEEK for PRINTING connected with this module/course? (printing web pages, emails, on-line conference messages, assignments, etc.) (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Roughly, how much OTHER paper do you normally use IN A TYPICAL WEEK for tasks connected with this module/course? (e.g. photocopying, etc). Exclude paper used for taking your own notes and for handouts provided by tutors etc. (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q17 - During THE WHOLE MODULE/COURSE approximately how many books did you buy mainly for your study of this module/course?

Books and reports: (Exclude books or other publications borrowed or used in libraries.)

(Please select one response only)

- ☐ None (1)  
☐ One (2)  
☐ Two (3)  
☐ 3 to 5 (4)  
☐ 6 or more (5)

q18 - During THE WHOLE MODULE/COURSE approximately how many other publications did you buy mainly for your study of this module/course?

Other publications e.g. journals, specialist magazines, additional newspapers: (Each item or issue purchased counts as one.)

(Please select one response only)

- ☐ None (1)  
☐ 1 to 5 (2)  
☐ 6 to 20 (3)  
☐ 21 or more (4)  
☐ Don't know (5)

i6 - We'd like now to ask about your use of energy associated with studying the module/course.

q19 - Is your usual term time residence:

(Please select one response only)

- ☐ A university or college hall of residence (1)  
☐ A flat or house (2)  
☐ A room in house or flat, lodgings, etc. (3)  
☐ Your permanent, usual, or main home (4)  
☐ Other, please specify: (5) \_\_\_\_\_

If Option Q19 (4) is selected GOTO Q20-23 Otherwise GOTO Q24

---

q20 - Has studying this module/course required any ADDITIONAL heating of your usual term-time residence?

*(Please select one response only)*

- ☐ Yes, frequently (1)  
☐ No, or only occasionally (2)  
*If Option Q20 (2) is selected GOTO Q21*

---

q20a - Could you estimate the average additional hours you heated your residence? (during the months this residence is normally heated).

*(Please select one response only)*

- ☐ 1 to 2 hours per week (1)  
☐ 2 to 4 hours per week (2)  
☐ Over 4 hours per week (3)

---

q20b - How is your residence heated during these additional hours?

*(If more than one heat source, choose the main one.)*

*(Please select one response only)*

- ☐ Central heating (from mains gas regular boiler) (1)  
☐ Central heating (from mains gas condensing boiler) (2)  
☐ Central heating (from mains gas combination boiler) (3)  
☐ Central heating (from oil boiler) (4)  
☐ Central heating (from solid fuel boiler) (5)  
☐ Central heating (electric storage heaters) (6)  
☐ Central heating (from heat pump system) (7)  
☐ Electric room heater (e.g. electric fire, fan heater, electric night storage heater) (8)  
☐ Mains gas room heater (e.g. gas fire, 'coal-effect' fire) (9)  
☐ LPG (bottled gas) room heater (10)  
☐ Closed biomass or wood fuel heater (11)  
☐ Closed solid fuel heater (e.g. coal stove) (12)  
☐ Open solid fuel heater (e.g. open coal or wood fire) (13)  
☐ Other, please specify: (14) \_\_\_\_\_

---

q21 - Has studying this module/course required any ADDITIONAL lighting in your residence?

*(E.g. when doing tasks for the module /course)*

*(Please select one response only)*

- ☐ Yes, frequently (1)  
☐ No, or only occasionally (2)  
*If Option Q21 (2) is selected GOTO Q22*

---

q21a - Could you estimate the average additional hours you have had to use lighting for your studies

*(Please select one response only)*

- ☐ 1 to 2 hours per week (1)  
☐ 2 to 4 hours per week (2)  
☐ Over 4 hours per week (3)

q21b - Does the place where you usually study (your term-time or home residence) have low energy lighting (fluorescent tubes or compact fluorescent lamps, or LED lamps)?

(Please select one response only per row)

	Yes, all low energy lighting (1)	Yes, some low energy lighting (2)	No low energy lighting (3)	Don't know (4)	Not applicable (5)
Term residence (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Home (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q22 - What type of home printer do you use?

(Please select one response only)

- ☐ Monochrome laser printer (1)  
☐ Inkjet printer (2)  
☐ Laser Multifunctional device (MFD) (3)  
☐ None (4)

q22a - Could you estimate the average hours you have used your personal printer when studying from home?

(Please select one response only)

- ☐ 1 to 2 hours per week (1)  
☐ 2 to 4 hours per week (2)  
☐ Over 4 hours per week (3)

i7 - And finally.....

q23 - Have you any comments to make about reducing environmental impacts associated with your studies?

q24 - If greater use of ICT's could reduce the environmental impacts of Higher Education teaching, would it be a good idea to use more ICT's to support the learning provision?

- ☐ Yes (1)  
☐ No (2)

q24a - Please explain:

STOP

**Complete** – You've now successfully reached the end of the survey

*Thank you very much for your help and co-operation. You will now be redirected to the SusTEACH webpage. Enquiries: Dr Sally Caird and Professor Andy Lane Faculty of Technology, Maths and Computing The Open University, Walton Hall, Milton Keynes, MK7 6AA, (United Kingdom). Tel: +44 (0)1908 653970 email: s.caird@open.ac.uk*